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United States Coast Guard operational information systems : improving functionality and cross-functionality.

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NAVAL POSTGRADUATE SCHOOL
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THESIS

UNITED STATES COAST GUARD
OPERATIONAL INFORMATION SYSTEMS:
IMPROVING FUNCTIONALITY AND
CROSS-FUNCTIONALITY

by

Peter S. Marsh

June, 1991

Thesis Advisor: James C. Emery

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The effective use of information can enable a public agency to better serve the taxpayers, or provide a crucial strategic advantage for a private sector firm. Present U.S. Coast Guard information systems do not provide information to all potential users as effectively as they could. They suffer from several shortcomings:

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- Significant overlap in content, resulting ion increased workload and frustration for field personnel who enter data and data inconsistencies between applications.
- Poor user interface design, resulting in a situation where although information may be accessible to a user, it is difficult to retrieve and therefore not gotten.

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(item 19, continued): greatly improved by developing a cross-functional Operations System (OIS). Developing such a system is critical to continued effective service to the public, but may require changes in the ways in which systems are developed and funded.

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United States Coast Guard Operational Information Systems: Improving Functionality and Cross-Functionality

by

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B.S., United States Coast Guard Academy, 1982

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ABSTRACT

The effective use of information can enable a public agency to better serve the taxpayers, or provide a crucial strategic advantage for a private sector firm. Present U. S. Coast Guard information systems do not provide information to all potential users as effectively as they could. They suffer from several shortcomings:

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Cross-functional systems, based on a robust information architecture, offer the potential to dramatically improve information flow and availability within an organization. In the Coast Guard, the flow of operational information can be greatly improved by developing a cross-functional Operations Information System (OIS). Developing such a system is critical to continued effective service to the public, but may require changes in the ways in which systems are developed and funded.

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LIST OF ABBREVIATIONS

ADS™	Application Development System (A DBMS product)
AMMIS	Aviation Maintenance Management Information System
AMVER	Automated Mutual Assistance Vessel Rescue
ANT	Aids to Navigation Team
API	Application Programming Interface
AR&SC	Aviation Repair and Supply Center
AtoN	Aids to Navigation
ATONIS	Aids to Navigation Information System
AUTODIN	Automated Digital Network
bps	bits per second
BTOS	Burroughs Technology Operating System
C^2	Command and Control
C^3	Command, Control and Communications
C3I,C^3I	Command, Control, Communications and Intelligence
CASP	Computer Aided Search Planning
CDB	Corporate Database Project at CGHQ
CG	Coast Guard
CGHQ	Coast Guard Headquarters
CGST	Coast Guard Standard Terminal
CGSW	Coast Guard Standard Workstation
COMDTINST	USCG Commandant Instruction
COMDTPUB	USCG Commandant Publication
CO	Commanding Officer
COTP	Captain of the Port
CTOS	Convergent Technologies Operating System
DAM	Direct Access Method
DBMS	Database Management System
DENC	Data Element Naming Conventions
DL, DL#	Driver's License Number
DOD	Department of Defense
DOS	Disk Operating System
DOT	Department of Transportation
DSS	Decision Support System
EECEN	USCG Electronics Engineering Center
ELT	Enforcement of Laws and Treaties
G-M	Office of Marine Safety and Environmental Protection
G-MIM	G-M, Information Management Branch
G-N	Office of Navigation Safety and Waterways Management

G-NRS	G-N, Search and Rescue Division
G-NSR	G-N, Short-Range Aids to Navigation Division
G-O	Office of Law Enforcement and Defense Operations
G-OLE	G-O, Law Enforcement Division
G-OP	G-O, Planning Division
G-T	CGHQ Office of Command, Control, and Communications
G-TTC	CGHQ Computing Technology Division
GAO	General Accounting Office
GDOC	Geographic Display Operations Computer
GOSIP	Government Open System Interconnection Profile
GSA	General Services Administration
GUI	Graphical User Interface
HDN	Hybrid Data Network
IBM PC	International Business Machines Corp. Personal Computer
IMTEC	Information Management and Technology Division, GAO
IRM	Information Resource Management
IS	Information System
ISC	USCG Information Systems Center
ITDS	Information Transfer and Distribution System
LE	Law Enforcement
LEIS II	Law Enforcement Information System, version II
LEIS	Law Enforcement Information System
MIO	Marine Inspection Office
MIS	Management Information System
MS-DOS	Microsoft Disk Operating System
MSIS	Marine Safety Information System
MSN	Marine Safety Network
MSO	Marine Safety Office
MTDS	Message Transfer and Distribution System
NMEA	National Marine Electronics Association
OCC	USCG Operations Computer Center
OIRA	Organizational Information Requirements Analysis
OIS	Operations Information System
OPAREA	Operational Patrol Area
OPFAC	Operating Facility Number
OSI	Open Standards Interconnection
OSC	USCG Operations Systems Center
PC	Personal Computer
PC-DOS	Personal Computer Disk Operating System
PFD	Personal Flotation Device
PM	CGHQ Program Manager
POB	Persons On Board
POSIX	Portable Operating System Interface for UNIX Computer Environments

PSRS	Port Safety Reporting System
RDC	USCG Research and Development Center
REC	Regional Examining Center
RJE	Remore Job Entry
ROI	Return On Investment
RT	Radio Telephone
SAR	Search and Rescue
SARMIS	Search and Rescue Management Information System
SARMIS/DES	SARMIS Data Entry Subsystem
SARMIS/DSS	SARMIS District Subsystem
SEER	Summary Enforcement Event Reporting System
SIMS/ELT	Shipboard Information Management System for ELT
SQL	Structured Query Language
SSAMPS	Standard Semi-Automated Message Processing System
SSAN, SSN	Social Security Account Number
SW/SSAMPS	Standard Workstation SSAMPS
USCG	U. S. Coast Guard
VIIS	Vessel Identification Information System
WHEC	High Endurance Cutter
WMEC	Medium Endurance Cutter
WPB	Patrol Boat
X.25	Packet-switching Protocol of the ISO
XVT	Extensible Virtual Terminal
ZBB	Zero-Based Budgeting

I. INTRODUCTION

> Numerous studies have documented that the U.S. has been in the throes of an historic transition for the past two decades. The old industrial society that generated wealth in the form of capital goods and manufactured products is giving way to a new society valued in terms of intangible assets, such as knowledge and information processing. (*Business Week*, June 30, 1980).

> Firms preparing to meet the challenges of the 1980's will need a capable and sophisticated manager of corporate information. An organization's success will be dependent in large part on successfully managing its information resources. (Lucas, 1979, p. 114).

As predicted by the first quote, and like many government agencies and businesses, the United States Coast Guard is increasingly discovering the strategic importance of information. But it is also discovering the deep implications of the second quote -- namely, that it is not information in itself, but the effective use of that information, that is critically important. The effective use of information can provide private sector firms with significant competitive advantages. In a similar fashion, it can greatly increase the effectiveness of a government agency's service to the taxpayers.

Achieving this effective information use, however, is exceedingly complex. Many existing information systems fall short of their potential effectiveness, for a variety of reasons. And almost no organization has implemented a single system that integrates all facets of its operations. The Coast Guard today finds itself in this situation -- it has a large number of information systems in use, but no single system that summarizes information from all functions. Today's systems are fairly successful at collecting the information their designers specified, which is primarily for use by headquarters staffs. However, few offer their information to those staffs with any flexibility in presentation, and few distribute any of the information to other levels in the organization for use in operational planning or command and control. There is a great need for information to flow not only up the hierarchy, but also down it, as well as across the traditional functional lines within the organization.

There are two reasons for the present situation. First, most Coast Guard systems are typical of 1980's computing technology, in which only a few exceptional systems provided the complete information flow now possible. Second, information "owners" are sometimes reluctant to share it, since it represents organizational power. This "information parochialism" is present in the Coast Guard.

A. COAST GUARD PROGRAMS AND PROGRAM MANAGERS

The Coast Guard is responsible for four major roles: maritime law enforcement, national security, maritime safety, and marine environmental protection (COMDTINST 16000.21, 21 Sep 90). The first two each constitute operating Coast Guard "programs" of their own. Maritime safety includes several programs, including search and rescue, aids to navigation, boating safety, vessel inspection and documentation, and icebreaking.

Each of these programs is administered by a program manager at Coast Guard Headquarters (CGHQ). These officers and their staffs perform planning, programming, and budgeting for their respective programs, and are assisted by other "support" offices. The organizational structure at headquarters and in lower echelon staffs is a classic hierarchy, divided along functional lines.

B. RESEARCH APPROACH

The goal of this thesis is to make recommendations to increase the effective use of information by the Coast Guard, partly by a critique of existing systems. Rather than consider the entire suite of Coast Guard applications, the thesis examines a few representative systems, listed in Table 1. They were chosen for their mainstream position in the Coast Guard's suite of operational systems.

TABLE 1: COAST GUARD PROGRAM MANAGERS AND INFORMATION SYSTEMS.

Program:	Program Manager:	Information System:
Search and Rescue	G-NRS Office of Navigation Safety and Waterways Management, Search and Rescue Division	SAR database (data input via SARMIS/DES, SARMIS/DSS)
Law Enforcement	G-OLE Office of Operations, Law Enforcement Division	LEIS (data input via SEER, SIMS/ELT)
Marine Safety	G-M Office of Marine Safety, Security, and Environmental Protection	MSIS

The information systems included in this study are all intended primarily for decision support. They include transaction processing as a necessary means of data capture, but the bottom-line reason for their existence is that someone needs the information for decision making. The decisions to be made vary in type, but can be broken down into two broad classes for purposes of analysis (although most systems are used to some extent for both decision types).

The first category is decisions made at the operational and tactical levels. These are primarily command and control decisions, either in the short term or medium term. A typical short-term decision supported by MSIS is whether or not to perform a boarding on a particular vessel. The information required includes the recency of the last boarding, results of prior boardings, and any other information about the vessel. A typical medium term decision is whether to stage a boat or aircraft in a place where there normally would not be coverage; the information required includes the density and frequency of cases in that area at certain critical times of the week or year.

The second category is decisions made at the strategic level, primarily programming and budgeting.

C. FUNCTIONALITY OF OPERATIONAL SYSTEMS

The existing operational information systems are, for the most part, fairly mature. Each of the systems considered in detail here has been operational since the early to mid 1980's. They function fairly reliably, and the information they seek is collected with relatively low error rates, at least when compared to the manual systems they replaced.

(For instance, the SIMS/ELT program provides on-line validation during data entry, keeping error rates low. However, data entered via manually prepared SEER messages is frequently erroneous).

Existing systems are still primarily aimed at collecting data for a limited range of uses at headquarters. Few allow any flexibility in their reports, or any interactive manipulation of the data to a form that would suit the user. Similarly, few provide any decision support to mid-level planners and operational personnel, where information could be extremely important to the agency's mission execution. Those that do provide this type of support are difficult to learn and use effectively.

The existing generation of standalone systems could be made much more effective on their own merits if improvements were made in four key areas:

- Human interface -- users' ability to learn the system quickly and use it easily once learned.
- Information accessibility -- systems should provide information in any form desired by the user, and make it easy for the user to describe what is desired. They should provide information to users at all organizational levels, not just the top.
- Data communications -- records should be transmitted to the central database before the value of the information decreases because of its age. The simple transmission of data should not cause users delay or frustration, but rather should be transparent.
- Source-level data validation -- records should be verified for accuracy at the source, leaving only minimal need for validity checking at the central site (i.e., to check for errors introduced during transmission).

Chapter III will discuss these aspects of the Coast Guard's information systems in detail.

D. CROSS-FUNCTIONALITY OF OPERATIONAL SYSTEMS

As a result of the individualized system development, with no coordination between program managers, there is little connectivity and no cross-functionality between Coast Guard information systems. In its 1990 report on Coast Guard Information Resources Management, the General Accounting Office (GAO) writes that:

> During the 1980's, the Coast Guard acquired new, expanded responsibilities - most notably drug enforcement and defense-related activities - in addition to its traditional missions of search and rescue, marine environmental protection, law enforcement, and defense readiness. In this multimission environment, the Coast Guard depends on getting large amounts of information, getting it accurately, and getting it on time. In many cases, however, information is not collected, readily available, or easily transferable among various Coast Guard units. These problems have affected both program operations and program management.
>
> The Coast Guard's law enforcement program, for example, suffers from a lack of readily accessible information necessary to support tactical decision-making. In deciding whether or not to board a vessel, timely access to information such as prior boardings or violations is essential to improving law enforcement.
>
> ... Many of the Coast Guard's information systems were developed to support narrow program needs. Most systems are not integrated and cannot share information with other existing Coast Guard systems.... field offices sometimes have to use several different systems to obtain information on the variety of interrelated tasks they are performing. (GAO/IMTEC-90-32, April 1990, pp 2-4).

This lack of cross-functionality is especially critical at field units: although one mission is usually primary, two or three other missions are also performed frequently. Consequently, information from separate systems is necessary to do a job well.

As an example, consider the Group operations center controller who gets a report of an overdue vessel. These reports are received frequently by the Coast Guard, and are characterized by very sketchy information and high levels of concern. Rarely does the Coast Guard get a good description of the missing boat, its operator, or the operator's habits and plans. Most of these reports are made in the evening -- a typical voyage, especially by a recreational boat, is most likely to end in the afternoon, and the report is made when boat is a couple of hours late.

In this situation, what an operations coordinator needs most of all is information. First, a good description is vital, because the boat must be described to all who may have seen it, such as marina operators, other boaters, or other agencies. Second, reporting sources often don't even know who owns the boat; if that information is available, a phone call to the owner or another related party may find that there was a change of plans, or that the missing party is safe in another port. Finally, LEIS contains records of all vessels sighted by Coast Guard units on patrol, and a check of that system may yield a sighting of the boat, which can narrow down the search area tremendously.

This information is quite likely to be in one or another of the systems considered in this thesis. However, getting it is quite difficult. SARMIS does not allow local access to its data at all. SIMS/ELT does create a local database of reports by the individual unit; however, it doesn't contain information from the neighboring station that may help. LEIS contains information reported by all units in the Coast Guard, but access was recently provided to Group offices (it had previously been restricted to districts and above, for security and access reasons). Finally, MSIS contains vital ownership information on any commercial or documented vessel, but almost no Group offices have access to that system. Even if the operations center coordinator had access to these systems, getting the desired information is difficult because of complicated query procedures that are different in each. A single, cross-functional system with a friendly user interface would surely be a boon.

Chapter IV will examine current views on the tradeoffs involved in implementing cross-functional information systems. Chapter V will apply this material to Coast Guard's IRM situation.

E. FUTURE SYSTEMS DEVELOPMENT PATH

The Office of Command, Control and Communications (G-T) at Coast Guard Headquarters is committed to ensuring that the Coast Guard develops systems which are increasingly cross-functional, and rely on open systems technology (USCG COMDTINST 5230.41, Aug 31 1990). Future systems development could take any of several paths, including the following (listed roughly in order of increasing difficulty and cost):

- Continue routine life cycle maintenance and upgrades, but expend no effort toward integrating systems. Leave the data structures as they are, primarily file processing based.
- Develop common user interfaces, so that each system looks and feels somewhat familiar to an operator who has previously used another system. However, make no other fundamental changes.
- Develop a query interface that can extract data from any of the different underlying systems while presenting only a single interface to the user.
- Employ database management systems, and develop similar architectures, data structures and data dictionaries for the various information systems to allow easier connectivity.
- Develop a completely integrated information system to replace the existing ones, scrapping the old systems entirely.

The first path, the status quo, has been criticized within the Coast Guard and by the GAO; it is well recognized that greater connectivity and cross-functionality are required. The degree to which those goals should be pursued, and the rapidity with which we pursue them, are the tough questions. Some work is already in progress:

- The Corporate Database Project is a Decision Support System (DSS) whose database management system extracts data from several existing CG IS's, aggregates it, and provides a user with analytical models and a graphical user interface to allow sophisticated interactive manipulation of information for programming and budget decisions (Synetics Corp, 1990, p. 1).

- The Office of Command, Control and Communications (G-T) has structured the CG Standard Workstation contract so as to encourage use of either Oracle™ or Progress™ as the DBMS, in order to establish a compatibility baseline.

- Policy requires that all new systems maximize implementation of open system architectures, in order to allow for the most flexible possible upgrade paths and to enhance competition.

- A set of Data Element Naming Conventions have been developed, for improving compatibility between data dictionaries.

- Unisys Corporation, the Coast Guard Standard Workstation vendor, is implementing a two-pronged approach to incorporating a Graphical User Interface into BTOS application. First, it will support Microsoft's Presentation Manager™. Second, it has specified XVT™ (Extensible Virtual Terminal) as the API (Application Programming Interface) for BTOS applications. The resulting similarity between interfaces, along with increased ease of use, should make information much more accessible.

F. RESEARCH FOCUS

The primary purpose of this thesis is to suggest three ways in which the Coast Guard can improve its collection and use of information. First, where possible, it should improve the existing independent, functionally oriented (stovepipe) systems. Second, it should aggressively develop *cross-functional* (or integrated) information systems. Third, and in close coordination with the second, it should develop a robust information architecture. This will be vitally important to all future systems development, whether the systems support a single function or are cross-functional.

The thesis begins with an overview of existing Coast Guard information systems, and recommendation for improving their standalone functionality.

The research then turns to the subject of cross-functionality. A theoretical foundation for the concept of cross-functionality is laid, founded in organizational structure, and the capability of information systems to support existing and new structures. These principles are then applied to the Coast Guard's missions, organization, and information systems. A proposal for a cross-functional Operations Information System (OIS) is made, and some thought is devoted to means of motivating such a system in a competitive budget climate such as the one in which Coast Guard program managers find themselves.

II. OVERVIEW OF COAST GUARD INFORMATION MANAGEMENT

This chapter presents a summary of present Coast Guard Information Resource Management (IRM) policy; a brief analysis of the recent past IRM policy atmosphere; an overview of the data communications schemes which support Coast Guard IRM; and a description of the Coast Guard Standard Workstation, which serves as the data entry terminal for nearly all of the Coast Guard's information systems.

A. TOP-LEVEL GOALS, POLICIES, AND OBJECTIVES

The highest level policy statement on IRM is found in Commandant Instruction 16000.21, the *Strategic Agenda* of Coast Guard Commandant Admiral J.W. Kime. In this document, he states his desired emphasis for the Coast Guard's four primary operational roles (see section I.A.), as well as for two important support areas, (1) personnel support, and (2) information, facility, and hardware management. His IRM-related goals are:

- Project future needs for equipment, capital and real property, and assess the condition, life expectancy and utility of inventory to meet current and future requirements,
- Maintain a capital asset projection plan to meet current and projected needs, and
- Increase efficiency and enhance capability through Information Resource Management.

The IRM–related policies in support of these goals are:

- Continually survey new technologies and applications of technology which would improve the Coast Guard's efficiency or effectiveness,
- Upgrade facilities and equipment as roles change, new technologies are employed, or obsolescence is identified, and
- Acquire standardized equipment which improves interoperability with other agencies and is fully supportable within Coast Guard or other federal government resources (COMDTINST 16000.21, 21 Sep 90).

Primary Coast Guard IRM policy in support of the Commandant's *Strategic Agenda* is contained in two documents: Commandant Instruction (COMDTINST) 5230.41, and COMDTINST 5230.38.

COMDTINST 5230.38, *Designated Senior Official (DSO) for Information Resource Management (IRM),* begins by defining IRM:

> IRM was officially introduced into the Federal Government by the Paperwork Reduction Act of 1980. This Act defines IRM as "...the planning, organizing, directing, training, promoting, controlling, and management activities associated with the burden, collection, creation, use and dissemination of information by agencies, and includes the management of information and related resources such as automatic data processing equipment.: To emphasize the importance of IRM in the Government, this Act requires the Senior Official in each agency to designate a DSO for IRM. (COMDTINST 5230.38, 30 May 90).

The instruction then appoints the Chief, Office of Command, Control, and Communications (staff symbol and common shorthand reference: G–T), a Rear Admiral, as the Coast Guard's DSO for IRM. His responsibilities are described in broad terms.

Further policy guidance is found in COMDTINST 5230.41, *Information Resource Management.* It recognizes the state of the existing suite of systems, then looks to the future:

> Most of our existing information systems were developed to meet individual program needs. This approach, while reasonable at the time, has led to many current management and information system problems, including those of conflicting, erroneous, and redundant data, and gaps between program-specific systems. The Coast Guard is fortunate because it now has a widely-developed infrastructure of standard information technology[1], and this infrastructure is becoming more capable and better interconnected every day. It is now practical to use this infrastructure for developing cross-program or cross-functional information systems to enhance our mission effectiveness.
>
> ... A CFS [Cross Functional System] is an information system that supports organizational processes relating the activities of several programs or functional divisions, rather than the activities of a single program. (COMDTINST 5230.41, 30 May 90).

Of special note in this instruction are several *IRM Principles:*

> The following principles shall guide Coast Guard IRM. They establish the relationships between the IRM oversight and support roles of Commandant (G-T) and the direct IRM responsibilities of our major programs:
>
> a. IRM activities which support improving the way of doing business are preferred to those which simply automate or replace existing functions.
>
> b. Individual IRM solutions may be suboptimized for the greater good of the Coast Guard.[2]

---

[1]This standard technology (the CG Standard Workstation) is not always implemented in a standard fashion, however. This results in a good set of tools, but not quite yet a solid infrastructure. (Squires, 1991).

[2]This deceptively simple statement is arguably the most important and most difficult to achieve IRM policy. See chapter VI for a further consideration of the issues involved.

... d. All Coast Guard locations will be interconnected with integrated telecommunications facilities.

e. Major organizational elements shall have direct IRM responsibilities.

f. Commandant (G-T) has the dual roles of Coast Guard IRM oversight and C3I infrastructure support.

... i. The Coast Guard will minimize data redundancy and multiple data entry activities. The ultimate goal is single point data entry. (COMDTINST 5230.41, 30 May 90).

Finally, this instruction presents a rationale for implementing cross-functional systems, in a Coast Guard context. This will be expanded upon in Chapter IV, which discusses recent work in the field of organizational design and the increasingly critical role of information systems as a cornerstone of the successful organization.

B. RECENT PAST IRM POLICY ATMOSPHERE

The Coast Guard has not viewed information systems as a strategic tool for changing the way of doing business. In large part, the systems now in place serve simply to gather data, and perhaps do so in a slightly more efficient way than the paper-based systems they replaced. However, they are all independent systems, with no interaction between each other, and there is huge data redundancy. The data redundancy costs the Coast Guard significantly, in several ways:

- In wasted time by field unit personnel who have to enter the same data into several independent systems, manually re-keying the data each time.
- In storage and operations costs, since the data are maintained at several different sites around the country, each with dedicated personnel and equipment.
- In data inconsistencies which result from the separately maintained databases.

Not all the existing systems collect their data more efficiently than the older systems they replaced. In the case of SARMIS, the computer-based system is widely felt by field personnel to require two or three times as long, per typical case, as the paper-based system it replaced (somewhat more data is collected, but not enough to account for all the difference. The awkward user interface is a major contributor to the problem.)

This situation has prevailed until recently, mainly for two reasons. First, past information systems have been developed primarily by program managers, with little involvement from the IS professionals in the Coast Guard's IRM division, G-TTC. (Decentralization advocates would argue that this is the best way to develop systems, and for most application systems, that is probably true. However, see Chapter VI for a discussion of two special cases: cross-functional systems and an organization-wide information architecture.)

Second, G-TTC does not have sufficient authority (and is not in an organizational position) to oversee information systems initiatives. Accordingly, each has been developed from scratch by a different team acting without benefit of lessons learned from other projects and with little motivation to benefit the organization as a whole. To be fair, some program managers accuse G-TTC of not being responsive when approached about becoming involved in developing a new system. Regardless of the source of the problem, there remains the fact that not enough coordination has existed between the IRM overseer and the development staffs.

Fortunately, it seems that this may change. Program managers see the benefits of integrated systems and parallel systems development, and are cooperating much more closely in the generation of systems which are now in the planning stages. Top management has begun to give G-TTC more authority over systems development, partly by designating G-T as the "Designated Senior Official" for IRM.

C. DATA COMMUNICATION IN SUPPORT OF IRM

Almost all data entry for the information systems considered in this thesis is done on the standard workstation, then transmitted to the central database by one of several means. This section first describes the various data communications networks in use by the Coast Guard, then delineates the ways in which systems use them.

1. Coast Guard Data Communication Networks

a. AUTODIN:

For record message traffic between the major nodes of its communication system, the Coast Guard uses the Department of Defense's Automatic Digital Network. Major Coast Guard communication centers (CGHQ, Areas, Districts, and CommStas, etc.) have AUTODIN drops, where they interface between this long-haul network and the other networks described below.

b. SSAMPS and SW/SSAMPS

Since the Coast Guard has AUTODIN drops at only a few major nodes, the Coast Guard has built its own networks for relaying record messages to smaller units. The networks that perform this job are called DISTNETs (below). The interface between AUTODIN and the DISTNETs is the Standard Semi-Automated Message Processing System (SSAMPS). Earlier versions of SSAMPS used special-purpose Hewlett-Packard hardware at major nodes. A shift is underway to replace this hardware with general-purpose CG Standard Workstations (CGSW), giving rise to the new name SW/SSAMPS. This system is installed at the major nodes where AUTOIDIN drops are located, and interfaces between the Coast Guard and DOD networks.

c. DISTNET

The District Telecommunications Networks are distribution networks for record messages, used within a single district, and connected to SSAMPS. These networks are being converted from supporting record messages only to supporting general data transfer. Also, they are being converted from dedicated landlines to the new Hybrid Data Network (see below).

d. HDN

The Hybrid Data Network is a new system that will connect shore units. It will replace and consolidate several transmission services, including record messages, the independent network which supported MSIS, and several others. The HDN will allow three access methods for data transmission, providing flexible support to systems:

- Dedicated X.25 service: dedicated, leased packet switched lines, 4800 to 9600 bps. Terminal equipment is on-line at all times.
- Virtual Dedicated X.25 service: leased packet switched lines, 2400 bps. Terminal equipment appears on-line to the user, but is actually connected to a switched voice grade line when a connection is needed, and disconnected at other times. The network is able to "call" dedicated and virtual dedicated users.
- Asynchronous dial access: users must dial the network themselves; the function is not automatic, as with virtual dedicated service.

These access methods obviously have important effects on the systems. The first is appearance to the user: if there is dedicated or virtual dedicated access, the user feels as if the system is right there, since he or she does not have to worry about establishing the connection to the remote site. With dial-up access, on the other hand, the user has in the past seen the separation between local and remote systems clearly (and perhaps painfully), since establishing the connection has been done manually. The dial-up function is now being built into application systems by their developers. These systems rely on dial-up access from low-volume users, but automate the connectivity task for them after a one-time setup by the local system operator.

The second effect is timeliness. All three methods allow on-line updating and interactive querying of the host. However, the rapidity of on-line updates may not be necessary for some systems; it will be cheaper to save data until off-peak hours, and then transmit them in a batch.

e. SprintNet

This network, formerly called TeleNet, is operated by U.S. Sprint, and the Coast Guard (through an FAA contract) purchases data transmission services on it for the HDN (above). When the present contract expires on June 8, 1992, it will not be renewed; rather, services will be purchased from other carriers under the terms of GSA's new FTS2000 communications contract. Some hardware at Coast Guard sites is presently leased from Sprint along with the lines; this will be replaced with Coast Guard-owned equipment before the cutover date.

f. Electronic Mail

The standard workstation supports electronic mail using Unisys' B-Mail program. Each LAN constitutes a "mail center" (the exact configuration may vary somewhat), which is analogous to a post office. Large units with several LANs may have only a single mail center (a "capital" center) that serves all internal LANs. Messages can be sent to and from any user at any center, and any form of binary file can be "attached," allowing easy exchange of computer files. This system can also be used for record messages -- SW/SSAMPS uses B-Mail as its transport mechanism. One drawback is that the system requires intensive involvement by local system administrators.

g. ITDS

The Information Transfer and Delivery System replaces the Message Transfer and Delivery System (MTDS), and integrates transmission of data and record messages between districts. It uses B-mail and the HDN.

2. Information System Use of Networks

a. SARMIS

Until 1990, field units sent paper reports from SARMIS/DES (the Data Entry Subsystem) to their district offices, where they were keypunched by a DP staff into 80-column card images. District staff members then performed manual data checking and validation. Validated records were transmitted to the SAR database at headquarters by Remote Job Entry (RJE).

A recent upgrade, SARMIS/DES version 1.2, allows field units to send their data to the district by mailing floppy disks, or as attachments to electronic mail messages. There, district staffs enter data into SARMIS/DSS, the District Sub-System. Transfer from districts to the SAR database will continue to be done via RJE, but will use the HDN as the transfer network when its RJE capability is functional.

b. SIMS/ELT and LEIS

The original input mechanism for LEIS was SEER messages, manually prepared by field units and sent via SSAMPS and AUTODIN to the OCC in New York, where they were electronically scanned, checked, and entered in the database if valid. SIMS/ELT will prepare and send these messages automatically, and print a local copy of the message report. Alternately, the program can generate a report to be sent as an E-mail attachment (however, this mode is not yet suported at the OCC, so is not yet implementable). Data are transmitted directly to the central database, and are usually on-line within 24 to 48 hours.

c. MSIS

MSIS data are entered on-line by field users, in interactive sessions. The system has in the past used its own system of X.25 packet-switched lines, leased from SprintNet, but is transitioning to the Hybrid Data Network. Data are available to other users immediately after it they are entered.

D. COAST GUARD STANDARD WORKSTATION

In the early 1980's, when there was no clear choice of microcomputer and operating system[3], the Coast Guard conducted a competitive procurement for a general purpose microcomputer contract. This procurement promoted standardization, prevented a proliferation of incompatible equipment, and was intended to provide the service with state of the art microcomputer capabilities, which could be readily expanded. (Maes, 1987, p. 3).

1. Hardware

The hardware contract for the Coast Guard Standard Terminal, now called the Coast Guard Standard Workstation (CGSW), was originally awarded in June 1981 to C3, Incorporated, and called for fixed unit prices on equipment to be supplied in variable quantities, as commands needed the machine (Maes, 1987, p. 42). That contract was renewed several times, then recompeted and awarded to Unisys Corporation, which is presently the vendor for the CGSW.

The machines purchased under the original contract and subsequent renewals are similar to the IBM PC and its progeny in that they are based on the Intel 80x86 microprocessor series. However, the operating system, Unisys' BTOS (formerly CTOS), is different (see below). The growth in capabilities and numbers of personal computers at Coast Guard units has been similar to that in the rest of the business world. The CGSW has become an integral part of information use at every unit.

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[3]The dominant microcomputer operating system was CP/M, the IBM PC had not been introduced, and Apple was little-known.

2. Operating System

The Convergent Technologies Operating System (CTOS) was capable of networking, unlike other microcomputer architectures. The only technology for shared computing resources available at the time was minicomputers or mainframes with multiple dumb terminals. C3 was at that time unique in offering the ability to network smart terminals and share system services without the overhead of a minicomputer.

The operating system is based on a command language interface, similar to those in PC-DOS and basic Unix, with one exception: the user types in the command name, or any unique abbreviation thereof, presses <Return>, and is then presented with a fill-in form listing all possible parameters for that command, and indications of whether each parameter is required or optional. This is in contrast to DOS and Unix, wherein the user must type the command name and all parameters at once, and gets no prompting about parameters. The CTOS <Help> facility should be more meaningful, but for experienced users, like most system administrators are, this interface is very quick and easy to use.

3. User Interface

From a user interface point of view, the CGSW keyboard is significantly different from that of the IBM PC: there are dedicated keys for <Help>, <Finish>-ing applications, <Mark>-ing and <Bound>-ing text to be manipulated, and for scrolling text onscreen without changing the cursor's relative position. Dedicating and clearly labeling these keys makes it much easier for neophytes to learn applications, and for experienced users to use them, *if* the application software supports them well. For instance, if a user sees a key labelled <Help>, presses it, and gets a meaningful explanation of possible actions in the present context, then it has been successful. If the message is a general one and laden with computer jargon, then it fails to give the user the desired assistance.

Just as in the DOS world, CTOS/BTOS application software has had no standard interface until recently, when a small amount of standardization has been achieved. Most CGSW applications now display "softkeys", or labels that apply to the ten function keys, across the bottom of the screen, either continually or on demand. In some applications, such as B-Mail and SIMS/ELT, these very effectively take the place of a menu, changing their meanings as different actions are taken.

III. EXISTING USCG OPERATIONAL INFORMATION SYSTEMS

This chapter presents a picture of the state of Coast Guard information management by examining three existing operational information systems. The systems being considered were selected because they are used by a large proportion of Coast Guard units. Also, they represent a large part of the spectrum of decision types, supporting both tactical and strategic decisions. Sections A through C of this chapter describe in some detail the systems that support the Marine Safety, Law Enforcement, and Search and Rescue programs. Section D briefly describes some others, to lend the reader a sense of the scope of Coast Guard information and the present attempts to manage it.

A. MARINE SAFETY SYSTEMS

The Marine Safety Information System (MSIS) supports the headquarters office of Marine Safety, Security, and Environmental Protection (G–M). A replacement system, the Marine Safety Network (MSN), is in the planning stages.

1. System Background and Goals

In 1974, the office of Merchant Marine Safety developed the Vessel Inspection Information System (VIIS). In 1977, the Office of Marine Environment and Systems developed the Port Safety Reporting System (PSRS), for tracking violation histories of vessels calling at U.S. ports. In 1984, the two were combined to form the Marine Safety

Information System. A Vessel Documentation module was added to the system in 1988. (COMDTINST M5230.11A, p. 1).

The Marine Safety program has several responsibilities, including: inspection of vessels and facilities, documentation of vessels, licensing of maritime personnel, and protection of the marine environment. These are carried out by roughly 110 field units, including Marine Safety Offices (MSO's), Marine Inspection Offices (MIO's), Regional Examination Centers (REC's), and others. Because the vessels and people being regulated are highly mobile, a central clearinghouse for information about them is vital. MSIS serves as that central clearinghouse -- an interactive central database that is updated frequently by field units.

MSIS-supported decisions are both tactical ("should I inspect vessel XYZ when it enters port today?") and strategic (should the Coast Guard issue new tanker safety regulation AB1234?"). A secondary goal is to automate certain processes, as a time- and labor-saving tool.

After more than a decade of evolution, MSIS is more thoroughly integrated into the daily routine of marine safety personnel than any other operational information system in the Coast Guard. It serves as a source of information and as the primary tool for reporting operations; it is an effective means of sharing information about vessels between the many MSO's. This is not to say that it is completely well integrated; on the contrary, users still complain about some facets of the system. However, marine safety units could no longer perform their mission without MSIS, and it is the most heavily relied-upon operational system in use in the Coast Guard today.

2. User Interface

MSIS is menu-driven, making it easy for users to learn and use. One shortcoming of the existing system is that the entire screen display, menus and all, is sent over the telecommunications link between host and user. This means that it can take several seconds to completely refresh a screen display, slowing the session down significantly. Also, the menu structure is organized with respect to the information products stored in the data tables, rather than by function or purpose. This means that users must be familiar with the structure of the database in order to retrieve information from it. (Wilder, 1991).

3. Hardware, Software, and Telecommunications

Field units use CGSW's and modems to link with the host. The CGSW's employ no processor power in the present system, but act as dumb terminals. The host is a network of Prime minicomputers at Batelle Labs, Columbus, Ohio. Batelle created the Automated Construction of Transaction Systems (ACTS), a rudimentary 4GL, to generate FORTRAN code for the application programs, and relies on Total, a relational DBMS, for the data base. (USCG Agency Procurement Request, 1991).

4. Future development plans

CGHQ (G-MIM) is designing a follow-on to MSIS, which will be called the Marine Safety Network. It will stress interaction with other systems, including LEIS II and external databases. It will be a distributed system, using the processing power of remote CGSW's, and have a graphical user interface. It will rely on the Hybrid Data

Network for transport. Hardware and software configurations are yet to be determined, but will be based on open systems architecture. This will include POSIX–compliant operating systems (Standard Portable Operating System Interface for Computer Environments, FIPS PUB 151), GOSIP–compliant communications architecture (Government Open Systems Interconnection Profile, FIPS PUB 146), and SQL–compatible (Structured Query Language, FIPS PUB 127) database management system. (USCG Agency Procurement Request for MSN, 1991).

B. LAW ENFORCEMENT SYSTEMS

The headquarters office of Defense Operations and Law Enforcement, Law Enforcement Division (G–OLE), is supported by a combination of three systems described below. A replacement system, the Law Enforcement Information System version II (LEIS II), is in the development stage.

1. System Background and Goals

Before the mid–1980's, there was no central Coast Guard database of law enforcement information. Information was reported by teletype message from operating units to their district commanders, who typically retained some sort of paper file. Districts typically had different reporting requirements, although there was some standardization within Atlantic Area and Pacific Area, respectively. When units operated outside their normal areas, they had to check manuals for the different reporting requirements and message formats. In the mid–1980's, the Coast Guard standardized law enforcement reporting nation–wide. Operating units still submitted teletype messages, but now they were the same everywhere.

The new law enforcement message system iss the Summary Enforcement Event Reporting System (SEER). The messages are computer–formatted, with strictly defined fields. The fields make up "Event Lines," each of which becomes a database record.

The SEER messages are sent to operational commanders, and also to the Operations Computer Center in New York, where they are stored. The Law Enforcement Information System (LEIS) was then designed to allow program managers to retrieve information via modem connection from CGSW's.

Finally, in 1988, the Shipboard Information System/Enforcement of laws and Treaties (SIMS/ELT) was introduced. It automates the preparation of SEER messages, and creates a local database for the field unit's use. SIMS/ELT does not allow direct interaction or online updating of the LEIS database; it is strictly an input system. Input messages arrive at the OCC and are buffered, manually checked for errors, and then entered in batches. The input data can be available for retrieval in LEIS as soon as a few hours after the incident in the best case, but more typically between 24 and 48 hours later.

The existing system was designed mostly for strategic decision making by program managers. It was not accessible to field units until April 1991 (COMDT COGARD MSG 011755Z APR 91), so tactical support was not provided. One limited exception is that units were able to gain some information through voice radio requests to group and district offices, but this method was cumbersome.

2. User Interface

The LEIS interface is one of the most difficult among existing Coast Guard systems. Although a few menus are available, it consists primarily of a proprietary command line query language. Like all query languages, this one is extremely involved for the uninitiated. The Coast Guard operates week-long training sessions to indoctrinate users in LEIS, and most of the time is spent on the query language; however, because of the complexity of command-line languages in general, many still have trouble using all the capabilities of the system after completion of the school. LEIS supports information retrieval only; no on-line updating is allowed, since all input is via SEER or SIMS/ELT.

The SIMS/ELT interface, in contrast, is probably the best among present Coast Guard systems, and therefore will be described in somewhat more detail. It is a clearly organized form-based system, and keeps users aware of their progress and the big picture throughout a session. A typical data entry screen, for an Identification Event Line, is shown in Figure 1.

The form-based design of SIMS/ELT allows rapid data entry, in contrast to the SARMIS interface, which will be described in the next section. On-screen forms consist of several logically related data fields, and are rewritten only after a complete form is done, so users can move quickly between fields. Finally, it has a well-implemented on-line help function. A single press of the <Help> key brings up a box that describes the purpose and content of the record, or Event Line, currently being entered, and all fields within it. A second press yields a box with all valid codes for the present field.

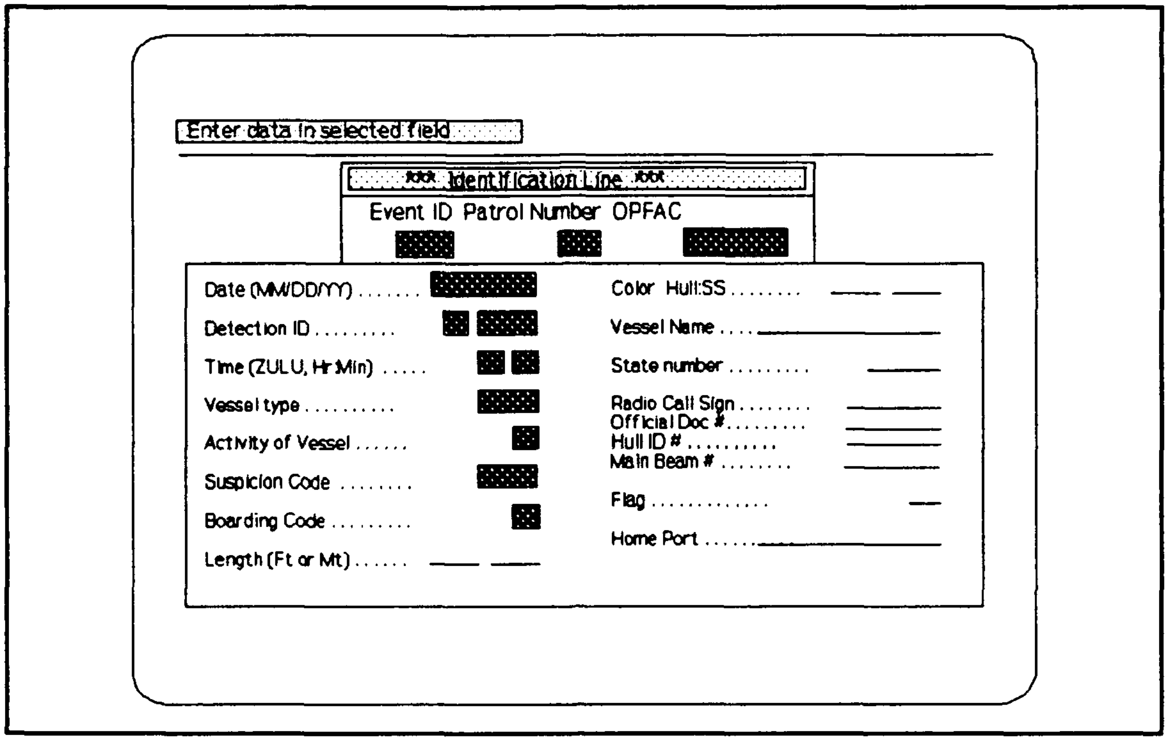

Figure 1: SIMS/ELT Identification Event Line data entry screen.

The SEER and SIMS/ELT system is based on events. Each event type is described by a line of data, and each has a dedicated data capture screen. The nine event types defined by the system are:

- OPAREA Employment
- Position
- Detection
- Identification
- Boarding
- Violation

- Last/Next Port of Call
- Crew
- Remarks

This organization of the reporting system into logical data records based on real-world occurrences makes it easy to understand and use.

3. Hardware, Software, and Telecommunications

SIMS/ELT runs on the CG Standard Workstation. LEIS runs on a PRIME 9955 mod 2 minicomputer at the Operations Computer Center.

LEIS was written in PrimeInfo by the Department of Transportation's Transportation Systems Center (TSC) in 1985. It has been modified extensively by Coast Guard personnel since its implementation. The hardware and software will be moved to the Operations Systems Center in Martinsburg, West Virginia when that facility opens in 1991.

SIMS/ELT was written by the Coast Guard's Electronics Engineering Center (EECEN), Wildwood, NJ. It is written in Application Development System (ADS), a 4th generation, forms-oriented programming language, for use on the Coast Guard Standard Workstation. ADS includes DBMS functionality for maintaining the local data base.

Data communications at present are by record message. SIMS/ELT supports E-mail transfers, but that option is not available at the OCC yet. In the former case, SEER messages are transmitted to the OCC as AUTODIN messages; this method usually uses SSAMPS from the unit to the district office, then either AUTODIN or ITDS to the

OCC. At the OCC, incoming SEER messages are scanned electronically into the batch update queue. Messages containing errors are marked for human intervention. In the latter case, SIMS/ELT sends SEER data as B-mail attachments. These are also collected in a batch queue. Since they are machine-prepared at the unit level, and SIMS/ELT employs validity checks, the error rate is much lower than for SEER messages, but a few are still rejected.

4. Future development plans

The follow-on system, LEIS II, has been designed, and coding will begin in mid-1991. The system will stress tactical decision support, with the goal of being available to field units with quick response times for board/no-board decisions. It will rely on a distributed architecture, with a central minicomputer as the server and remote CGSWs linked via various telecommunications channels. It will also stress open systems architecture, compliant with GOSIP, POSIX, and SQL. (System Resources Corp., 8/20/90).

C. SEARCH AND RESCUE SYSTEMS

The headquarters office of Navigation Safety and Waterway Management, Search and Rescue Division (G-NRS), is supported by a combination of three systems. SARMIS/DES (Data Entry Subsystem) is used at the unit level for data entry. SARMIS/DSS (District Subsystem) is used at district offices for compiling a district-wide database and to prepare data for upload to the central database. The SAR database is the central, Coast Guard-wide database.

1. System Background and Goals

For years, units submitted a SAR Assistance Report to CGHQ for every SAR case performed. The data was compiled in the SAR database, and used to justify budget requests and for strategic resource planning. Input remained in the form of the paper report, form CG-5151, until about 1986, when SARMIS/DES was implemented to automate the process and expand the amount of data collected. Finally, in 1989, SARMIS/DSS was developed, allowing district offices to compile their own district-wide databases and conduct error-checking before forwarding unit reports on to headquarters.

As mentioned above, the primary purpose of the SAR database is strategic decision support. A secondary use of the SAR database is to provide density plots and other decision tools for district, group, and unit planners; however, this support is provided off-line, requires a written request via the chain of command, and takes several weeks, so usability is low.

SARMIS/DES was designed to automate the data input process, and eliminate keypunching at headquarters. However, since it collects significantly more data than the old paper forms, users estimate that it takes roughly twice as long to document a case using the computer than it did with paper. The program provides the unit with a few pre-formatted monthly summary reports, but does not allow ad-hoc queries.

SARMIS/DSS runs on CGSWs at the district offices, accepting input in the form of data from SARMIS/DES. It validates data, then uploads it to the SAR database using RJE. It also provides an interactive database, written in C and Progress, which can be used for ad-hoc queries about SAR incidents within the district.

2. User Interface

The interface for the central SAR database is a command-line query language. However, there is no provision for remote access to the system by operating units. All requests for information are submitted to headquarters on paper, where a computer operator issues the database query and mails the report back to the requestor.

SARMIS/DES is operated by field unit personnel, usually the boat coxswain or a watchstander who was involved in a particular case. It claims to be interactive, but is so only in the data entry module. There is no capability to query the local database in an ad-hoc fashion. Units simply get pre-formatted monthly summaries and electronic reports to send to the district office. SARMIS/DES typically asks the user one question per screen, then clears it and rewrites the next question. This design makes it easy to learn, but very slow in general use, since users must continually refocus on the new screen and re-orient themselves to the question being asked. It also prevents the user from retaining a feel for progress through the program -- one quickly becomes lost in the maze of new screen displays. On-line help is limited; however, since each question is presented in such great detail on the primary data entry screen, this is not a terrible drawback. If a user is forced to stop data entry before a record is complete, there is no way to save what has been done so far, a serious drawback when data entry for each record takes from five to fifteen minutes.

3. Hardware, Software, and Telecommunications

The SAR database is hosted on an Amdahl mainframe computer at the Transportation Computer Center, Washington DC. The Coast Guard's access to the database is through an asynchronous 1200 bps terminal in the offices of G-NRS, where a single GS-11 employee performs maintenance and issues queries. Ten years' data are stored online; that comprises roughly 700,000 records, approximately 150 megabytes. The program was written in the late 1970's by personnel at the Transportation Systems Center using Focus™, a relational DBMS.

SARMIS/DSS and SARMIS/DES both run on the Coast Guard Standard Workstation. SARMIS/DSS is written in C and Progress, a fourth-generation language and DBMS. It was developed in 1989 by Ship Analytics, Incorporated, under contract to the Coast Guard Research and Development Center. SARMIS/DES is written in Pascal. It uses Direct Access Method (DAM) to access the data, not a DBMS.

SARMIS/DES data can be sent to the district office by E-mail, record message, mailing floppy disks, or mailing paper reports. From the district office to headquarters, data is sent over a synchronous 9600 bps line, using RJE (remote job entry) software.

G-NRS will shift to the Hybrid Data Network in late 1991, when the BTOS version of RJE has been modified to support the X.25 protocol.

Mailing paper reports and floppy disks from units to the district is becoming increasingly rare, with most units using E-mail and a few using messages.

4. Future development plans

The SAR database has several shortcomings. It still uses only the limited set of data collected by the paper forms CG-5151 before 1986, not the full range of information collected by SARMIS/DES. It is the only application still using FOCUS at the DOT computer center, and there is pressure from system operators there to migrate to another language, perhaps Oracle.

SARMIS/DES will be rewritten soon to move away from Pascal and DAM, and into a DBMS that allows flexible queries locally. G-NRS is cooperating with G-OLE, G-OP, and the RDC to investigate a sortie-based data collection front end, which will collect data only once, then feed it to the systems that need it. It could use the Geographic Display Operations Computer (GDOC) system when that becomes operational.

D. OTHER USCG INFORMATION SYSTEMS

This section describes some of the Coast Guard's other information systems, to provide the reader a sense of the scope of Coast Guard information management.

1. CASP

Computer-Assisted Search Planning, or CASP, is more a computational program for modelling and planning maritime searches than an information system; the data entered by an operator are used only as inputs for the program to predict drift and search areas, and are normally not saved for review by program managers. It is an interactive, menu-driven program hosted on a PRIME 9955 minicomputer at the OCC. It will move to the OSC in Martinsburg, WV.

2. AMVER

Automated Mutual Assistance Vessel Rescue, or AMVER, is one of the oldest systems in use by the Coast Guard. It was developed in the mid-1960's, pursuant to international search and rescue agreements, in order to track seagoing ships. These ships voluntarily submit sail plans, which are keypunched into a database in the PRIME 9955 minicomputer at the OCC. The system is accessed by rescue coordinators and search planners, so that during a distress at sea they may quickly determine what vessels are nearby and radio them directly for assistance. A follow-on, AMVER 2, is under development, to provide better access and output.

3. OTHER SYSTEMS

There are many more systems in use or under development. Tables 2 and 3 show those listed in the Coast Guard's IRM plan in July 1990. (source: COMDTPUB P5230.43, 18 Dec 90, pp. 19-21).

TABLE 2: USCG INFORMATION SYSTEMS.

Acronym:	*System Description*:
STARS:	TRACEN Petaluma Student Tracking and Reporting System
DMPS:	International Ice Patrol Iceberg Data Mgmt and Prediction System
DAFIS:	Departmental Accounting and Financial Information System
IMAGE:	Information Systems Division Image System
LUFS:	Large Unit Financial System
AMIS:	Acquisition Management Information System
DIAS:	District Interim Accounting System
FINAIDS:	Headquarters Accounting System
ASIS:	Aviation Supply and Inventory System
ACMS:	Aviation Computerized maintenance System
CEDS:	Civil Engineering Data System
BEST:	Base Engineering Support, Technical
CBMIS:	G-ELM's Configuration Based Management Information System
MMS:	Defense Logistics Materiel Management System
SAIL:	G-ELM System for Automated Integrated Logistics
ULMS:	Unit Logistics Management System
NEDMIS:	Naval Engineering Division Management Information System
CAD:	Naval Engineering Division Computer-Assisted Design System
HSMIS:	Health Services Management Information System
TMPS:	Tri-Service Micropharmacy System
CLAMS:	Clinic Automated Management System
NIPS:	NonFederal Invoice Processing System
HAZMAT:	Hazardous Material Information System
SHARKS:	Safety/Health/Accident Relational Key System
MADCAP:	Medical and Dental Clinic Automation Program
LAW:	Legal Automated Workstation
LDR:	Legal Document Research
MSN:	Marine Safety Network
VIDS:	Vessel Identification and Documentation System
AUXMIS:	Auxiliary Management Information System
RBS:	Recreational Boating Safety System
BRAINS:	Bridge Administration Information System
AMVER2:	Automated Mutual Assistance Vessel rescue System
CASP:	Computer Assisted Search Planning System
LOIS:	LORAN-C Operations Information System
BAMS:	Boat Administration and Management System
ATONIS:	Aids to Navigation Information System
AAPS:	Automated Aid Positioning System

TABLE 3: USCG INFORMATION SYSTEMS, CONTINUED.

Acronym:	*System Description:*
ACMS:	Aid Control and Monitoring System
CAP:	Computer Assisted Positioning
ENMS:	Electronic Notice to mariners System
VTS H/G ABDS:	VTS Houston/Galveston Automated Bright Display System
SARSIM:	Search and Rescue Simulation Model
TECS:	Treasury Enforcement Communications System
JMIE:	Joint Maritime Information Element
SPI:	Security Program Improvements
EMIS:	Enforcement Management Information System
LEIS II:	Law Enforcement Information System II
ELT/SIMS:	Enforcement of Laws and Treaties/Shipboard Info Mgmt System
OPSTAT:	Abstract of Operation Software
SRA:	Computer for Service Record Automation
PMIS/JUMPS II:	Personnel Mgmt Info System/Joint Uniform Military Pay System
PDS:	Personnel Decision System
TRAVEL:	Travel Claim Automation
RIMS:	Recruit Information Management System
PXM:	Exchange and Morale Systems
PC SYSTEMS:	Civilian Personnel Systems
CIRMS:	Classified Information Resource Management Support
DRMIS:	District Reserve Management Information System
MOBSYS:	Reserve Mobilization System
COMDAC:	Command, Display and Control System
STC II:	Shipboard Tactical Computer II
NAVMACS:	Naval Modular Automated Communication System
IRIS:	Incident reporting Information System
AISS:	Automated Information System Security
CGSWOA:	CG Standard Workstation Contract Office Automation
DRS:	USCG Data Repository System Project
MAP:	Minicomputer Acquisition Project
CDB/EIS:	Corporate Database / Executive Information System
DIS:	Distributed Information System
DCS:	Distributed Computing System
GTC:	Geographic Tactical Computer
OIS:	Operations Information Systems
SATCOMM:	Commercial Satellite Communications
COMMSTA:	Communications Station Automation
HDN:	Hybrid Data Network

E. SUMMARY

The existing suite of systems are vertically oriented file processing systems which have generally been built piecemeal around processing data files that began as paper reports. They have evolved as stovepipes because they mirror the way the Coast Guard structures its program management. They provide little in the way of distribution of data among Coast Guard information users, and less in the way of manipulation. They are hard to learn, awkward to use, and sometimes painfully slow at transferring information.

Recommendations for improving these systems are put forth in Chapter VII. But these improvements would be expensive -- they strike at the very hearts of the systems. And increasing the standalone functionality of existing systems may have a lower payoff than taking the next step, integrating the systems and re-engineering our information flow. The next three chapters examine the benefits of cross-functional systems, and propose a system that would increase the information payoff.

IV. CROSS-FUNCTIONALITY: A THEORETICAL FOUNDATION

The Coast Guard has recently begun focusing on cross-functional systems as key strategic elements for new development; the concept has quickly achieved buzzword status. Yet, as with any new buzzword, there is confusion about the concept of cross-functionality and exactly what constitutes a cross-functional system.

This chapter examines the conceptual basis for cross-functionality, beginning with a discussion of organizational structure: the need to organize, structures that have proven effective, and some of the problems inherent in organizing. The hierarchical and matrix structures are described. Discussion then turns to minimizing the limitations of these structural forms by establishing cross-functional organizational links, and means of supporting such a structure through information technology. Finally, a methodology for conducting the strategic MIS planning needed to achieve such a complex goal is reviewed. Chapter V will propose a cross-functional Operations Information System for the Coast Guard, relying on this theoretical framework.

A. THE NEED TO ORGANIZE

Simply put, human organizations have become far too large and complex to be understood, analyzed, and controlled in their monolithic entirety. Systems theory provides a convenient tool for breaking these huge entities down into manageable chunks. (Emery, 1987, p. 241).

1. A Systems Theory Approach

A large system has several subsystems, each of which has its own subsystems, until the activity at hand is reduced to a manageable level, typically something that can be performed by an individual or small group of individuals. Each subsystem is responsible for a certain portion of the overall goals, and the functions carried out within it are closely related to one another, at least as compared to other functions at that same level of organization.

Each system has a boundary, which defines the activities considered to be integral parts thereof. Things outside that boundary are part of its environment; things that cross the boundary of the system under consideration are its inputs and outputs. (Emery, 1987, p. 241).

As the number of subsystems within an organization grows, so do the number of interactions, or actions that cross subsystem boundaries. There are two primary sources of interaction: *coupling* and *shared resources* (see Figure 2). In coupling, the output of one subsystem is an input to another, so that any change in the output rate, quality, or other parameters from the first will impact the second. The same is true of shared resources, with the additional complication that the output from the first subsystem is used by more than one downstream subsystem. The output of the first is a resource, shared between the others; like any other resource, a

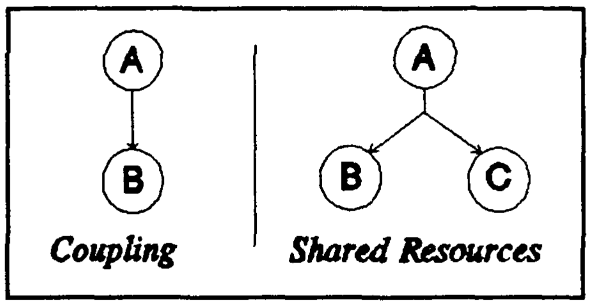

Figure 2: System interactions (after Emery, 1987).

scarcity produces tough decisions for the people who allocate it. If one of the downstream subsystems is considered more important than the other, it may get a proportionally larger share of the reduced resource; however, this creates even more problems if the process moves through other subsystems further downstream, in a domino or ripple effect. (Emery, 1987, pp. 243–44).

The first way to reduce the number of interactions, and therefore the degree of complexity, is to structure the organization so that work groups (subsystems) are responsible for closely-related tasks. If this is the case, each can cope with as many things as possible internally. In a similar fashion, closely-related work groups should be clustered together. Then, if a certain task cannot be completed within the subsystem, it can likely still be handled with a minimum number of interactions by merely passing it up one level, or horizontally to a related subsystem. This technique focuses on eliminating interactions altogether where possible.

Absent the ability to avoid interactions by structural means, as above, one can at least mitigate their effects through *decoupling*. Decoupling increases the isolation of a subsystem, thereby reducing the frequency or duration of interactions. There are several techniques for accomplishing this, as illustrated in Figure 3. One common technique is a buffer, which collects the outputs of the first subsystem until the second

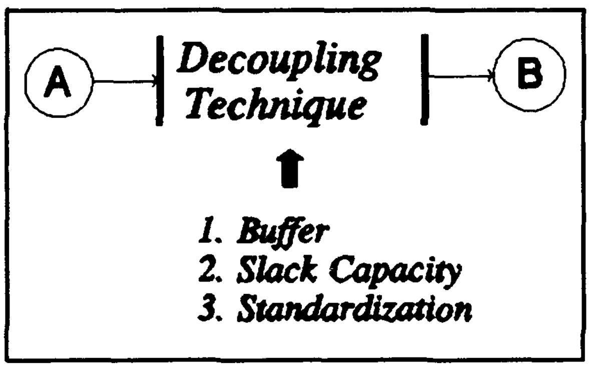

Figure 3: Techniques for decoupling systems. (After Emery, 1987).

is ready to receive them as inputs. Another is building systems with slack capacity, so that the rate of output can be adjusted depending on downstream demand or upstream supply. Finally, one can increase standardization. The consuming system decides under what range of conditions it can operate; if the output from the first system is within the specified limits of tolerance (whether these limits apply to rate, quality, or some other parameter), then the subunits do not need to coordinate. Only when there is an out-of-tolerance condition does coordination become necessary. (Emery, 1987, p. 249).

Interactions due to shared resources are a harder problem than those due to coupling. One of the best ways of reducing these interactions is through the use of slack capacity, despite its cost.

When the organization has exhausted ways of reducing the number and complexity of interactions, it must employ a coordination mechanism. This may be a human manager, or a process control computer; in either case, the task is to coordinate the interactions between the various subsystems. This may involve resource allocation decisions for subsystems, flow control, or responding to out-of-tolerance situations. Highly coordinated systems are often referred to as tightly integrated, and are characterized by tightly scheduled inputs and outputs, with extensive resource sharing. This has the advantage of greater efficiency for the system as a whole, allowing it to operate with fewer buffers and less slack capacity. Economies of scale may be realized. Perhaps most important, decisions can be made from the larger perspective of the system as a whole (or that of a larger set of subsystems), rather than from the perhaps suboptimal perspective of a smaller unit.

The problem of highly coordinated systems is that they are more complex, involving extensive interactions between subsystems. The benefits of integration versus independence must be weighed for the situation at hand, and an appropriate point along the spectrum from one end to the other chosen. Managers are now able to factor into this decision the fact that information technology, if properly applied, can simplify coordination.

2. An Information Processing Approach

Galbraith has described organization design principles from a point of view centered around the need to process information:

> If the task is well understood prior to performing it, much of the activity can be preplanned. If it is not understood, then during the actual task execution more knowledge is acquired which leads to changes in resource allocations, schedules, and priorities. All these changes require information processing *during* task performance. Therefore *the greater the task uncertainty, the greater the amount of information that must be processed among decision makers during task execution in order to achieve a given level of performance.* (Galbraith, 1974).

In developing his analysis of the organization's structure, Galbraith presents a model (reproduced in Figure 4) which shows seven methods for coping with the need to process information, broken down into three categories. First are those which reduce the need to process information in relatively small organizations. Second, and quite similar, are methods to reduce the need to process information as the organization grows increasingly large and complex. Third are methods to increase the ability of the organization and its subunits to process information. Notice that the first two of these methods correspond closely to the systems theorists' approach of increasing independence of subunits, while the third corresponds to increased integration.

Galbraith's methods 6 and 7 are the areas where information systems can greatly benefit the organization. Sharing information vertically and horizontally throughout the organization becomes feasible if, for example, all departments have access to a common database. In a mail order firm, a database with customer, order, and supplier information could be integrated across all functions so that order-processing clerks, packing and shipping clerks, billing clerks, and customer service clerks could all have access to the same information. Any of these people would be able to immediately get necessary, current information on the status of a customer or and order.

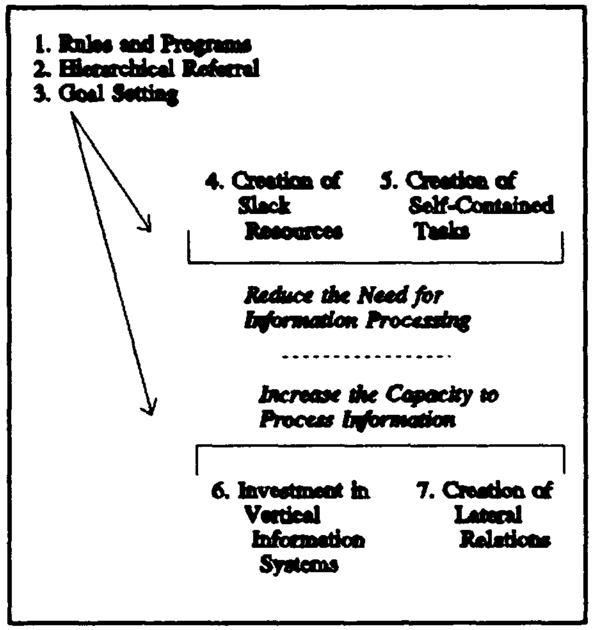

Figure 4: Organizational design strategies (after Galbraith, 1974).

B. COMMON ORGANIZATIONAL STRUCTURES

What organizational structures have evolved from this theory? In this section, brief descriptions of two broad categories are presented. The descriptions are of general concepts of the structures, not specific implementation details, and are presented as an introduction to the concept of cross-functionality.

1. The Hierarchy

Since the 1920's, when Alfred Sloan refined the model at General Motors, the functional hierarchy has been the most common structure in Western organizations (Norton, 1988). It is easy to understand, and embodies the span of control concept. It provides clear singularity of supervision (or command). Finally, it fits well with both the systems theory and information processing views of organization design: as tasks become increasingly specialized, they are moved to lower levels of the pyramid; higher levels coordinate between similar but distinct sub-units.

However, a major drawback is that hierarchical organizations can have their major divisions organized along only one of several possible dimensions, such as function, product, market, or geographical territory. Figure 5 shows a typical functional organization, with its major divisions structured about the tasks people perform, or the *inputs* to the work process.

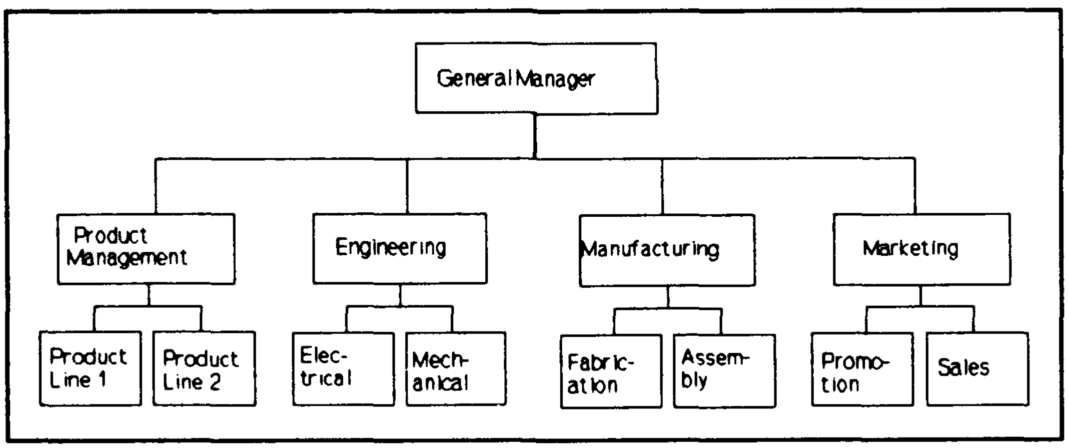

Figure 5: Hierarchical organization structure (after Galbraith, 1974).

2. The Matrix

The one-dimensional nature of the hierarchy has led several researchers to suggest alternatives, including the matrix organization. In this scheme, sub-units are organized along two dimensions at once; commonly these reflect the *inputs* to the work process (functional specialties) and the *outputs* (products). An example is shown in Figure 6. This firm has chosen to give primary control to managers in the functional dimension; other firms, with a more product-oriented culture, may reverse the roles.

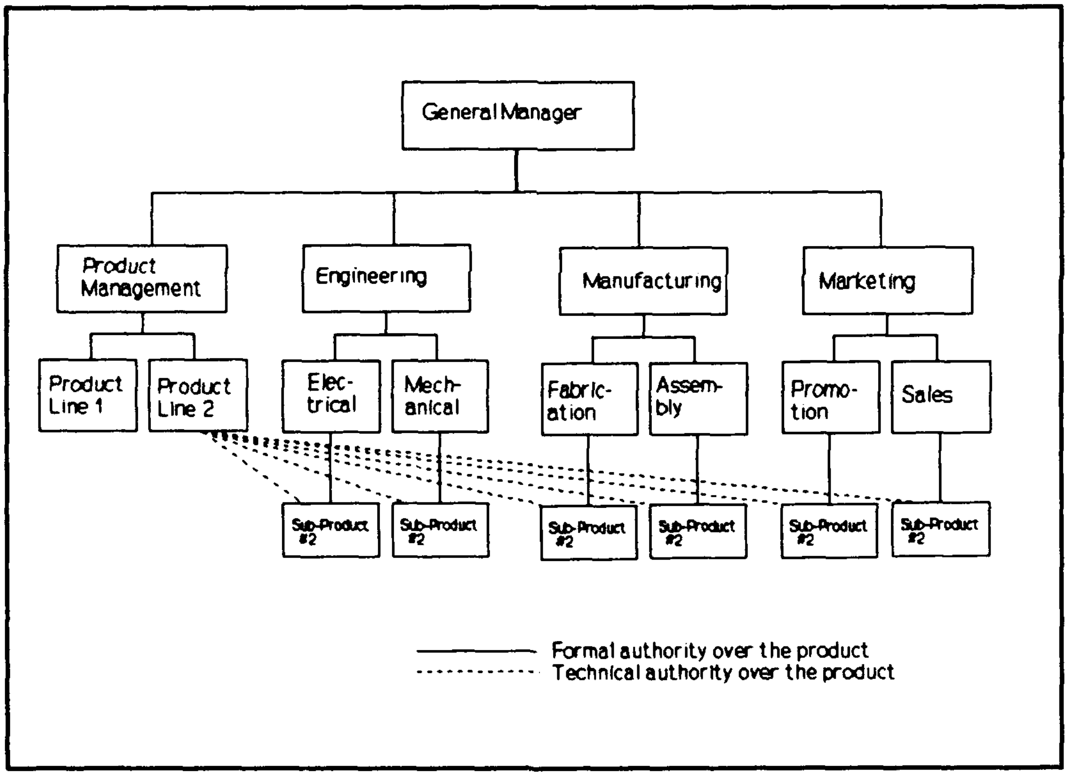

Figure 6: Matrix organization structure (after Galbraith, 1974).

3. Limitations of the Hierarchy and the Matrix

In their popular book, *In Search of Excellence,* Peters and Waterman survey many U.S. businesses, striving to find out what sets the most successful ones apart. Among the eight attributes they ascribe to an excellent organization is one with special significance for this discussion -- "*Simple form, lean staff*:"

> Along with bigness comes complexity, unfortunately. And most big companies respond to complexity in kind, by designing complex systems and structures. Then they hire more people to keep track of all that complexity, and that's where the mistake begins.... making an organization work has everything to do with keeping things understandable for the tens or hundreds of thousands who must make things happen. And that means keeping things simple. (Peters and Waterman, 1982).

The essence of simplicity, they say, is picking one of the several dimensions described earlier and making it the primary focus of the structure; they prefer product, because it naturally relates everything the division is trying to accomplish. The thing to avoid is a complex, intertwined structure, such as a matrix, where each employee has two (or more) bosses, and no clear picture of who's in charge today. They do not advocate abolition of the matrix structure, but point out that those corporations which have implemented it successfully all specify clearly which dimension of the matrix is the primary one. This reduces the potential for ambiguity and anarchy.

However, the need to keep things simple so that employees can cope with the size of the organization is only one side of the coin. On the other is the fact that functionally organized units frequently need to send information outside their own function, or branch of the hierarchy. Norton defines the building blocks of organizations this way:

> An *activity* is the basic element of organized work.... A *process* is a collection of activities that are linked together, adding value by converting fundamental resources to achieve organizational objectives....A *function* is a collection of activities that are organized together by a common discipline.... *Processes* are the means by which organizations act to accomplish their objectives. *Functions* are the way organizations group people to achieve the benefits of specialization. As long as processes are intrafunctional, management is relatively straightforward. However, *when function and process do not coincide, we create unnatural barriers to organizational effectiveness.* (Norton, 1988).

C. CROSS-FUNCTIONAL ORGANIZATIONAL STRUCTURE

The limitations of a rigid hierarchy have led Norton and others to propose a cross-functional approach to organizing. The concept focuses on analyzing work and information flows (Norton's *processes*) on the front line. It is similar to a product-oriented hierarchy, which emphasizes the organization's *outputs*; however, it goes a step further, focusing on enabling the front-line worker to handle all aspects of a work activity. Cross-functionality occurs when a single organizational unit has responsibility for more than one function. A classic case in which cross-functionality would yield dramatic improvements involves a bank with several functional departments:

> A large midwestern bank has several independent business units, each of which maintains its own customer information files and "guards them religiously." Customers with multiple transactions cannot get a consolidated statement. Further, the bank has no idea of its overall exposure to any particular customer, no idea of its overall profitability by customer, no way to truly segment its market, no way to cross-sell its services. (Index Group, 1990)

The quoted article points out the benefits that would be achieved by building a cross-functional information system: all departments would have access to the same information, top management would have access to consolidated information, and customers would perceive a logical, cohesive entity. This case is illustrated in Figure 7.

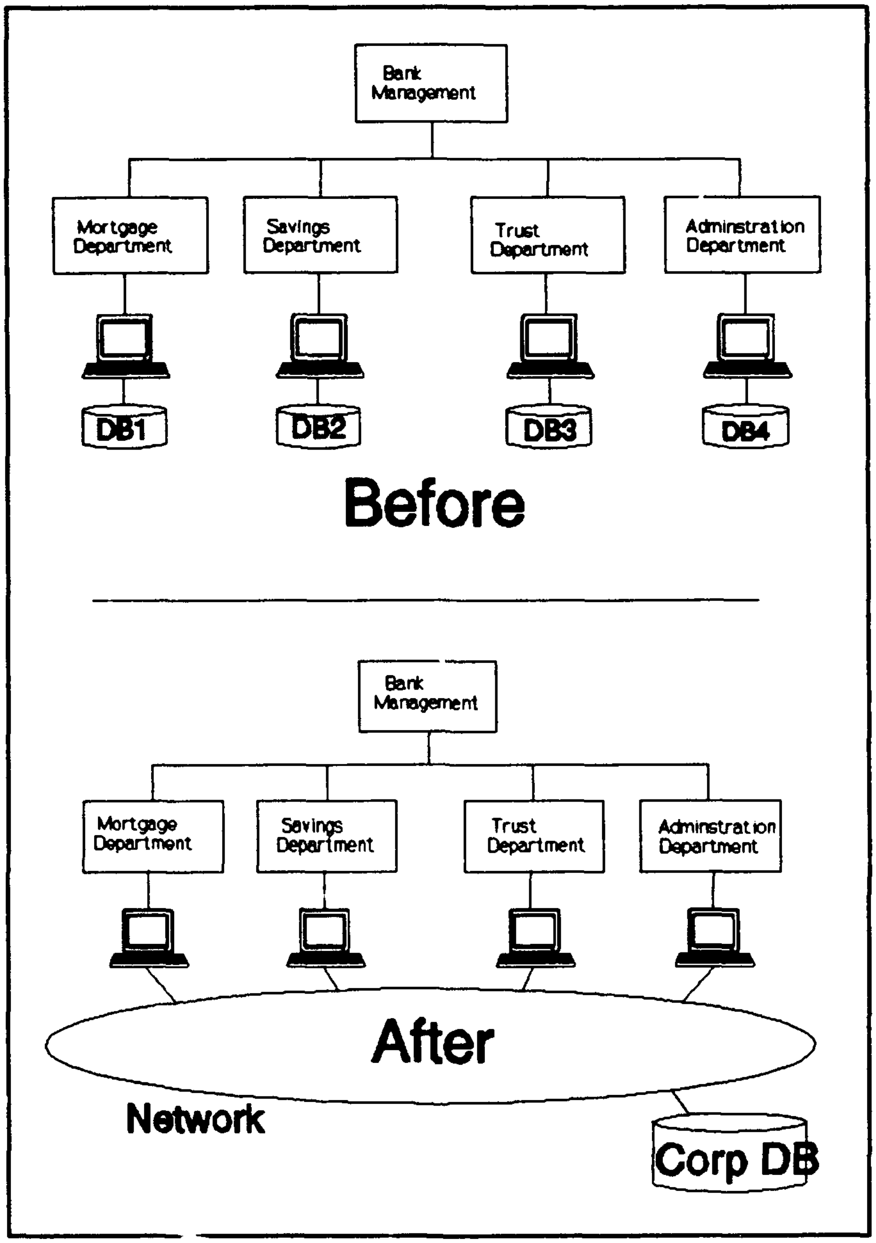

Figure 7: Banking example of cross-functional information system.

In this case, the bank has two options regarding the extent to which it employs cross-functionality. First, it could leave things at the level cited, integrating the information system but retaining its previous structure (loan department, savings department, etc). Second, it could redesign not only the IS, but also its structure. This concept is examined further in the next case.

Where the activity involves the customer, cross-functionality can be especially important, in the interest of presenting a single face to the customer. By creating an individual position, or at least a small business unit, to be able to respond fully to a customer's query, some companies have achieved enormous advantages. Here is a real-world example:

> Mutual Benefit Life, the country's 18th largest life carrier, has reengineered its processing of insurance applications. Prior to this, MBL handled customers' applications much as its competitors did. The long, multistep process involved credit checking, quoting, rating, underwriting, and so on An application would have to go through as many as 30 discrete steps, spanning five departments and involving 19 people. At the very best, MBL could process an application in 24 hours, but more typical turn-arounds ranged from 5 to 25 days -- *most of the time spent passing information from one department to the next* (emphasis added). (Another insurer estimated that while an application spent 22 days in process, it was actually worked on for just 17 minutes.)
>
> MBL's rigid, sequential process led to many complications. For instance, when a customer wanted to cash in an existing policy and purchase a new one, the old business department first had to authorize the treasury department to issue a check made payable to MBL. The check would then accompany the paperwork to the new business department.
>
> The president of MBL, intent on improving customer service, decided that this nonsense had to stop and demanded a 60% improvement in productivity. It was clear that such an ambitious goal required more than tinkering with an existing process. Strong measures were in order, and the management team assigned to the task looked to technology as a means of achieving them. The team realized that shared databases and computer networks could make many different kinds of information available to a single person, while expert systems could help people with limited experience make sound decisions. Applying these insights led to a new approach to the application-handling process, one with wide organizational implications and little resemblance to the old way of doing business.

MBL swept away existing job definitions and created a new position called a case manager. Case managers have total responsibility for an application from the time it is received until a policy is issued. Unlike clerks, who performed a fixed task repeatedly under the watchful gaze of a supervisor, case managers work autonomously. No more handoffs of files and responsibility, no more shuffling of customer inquiries.... MBL can now process an application in as little as four hours, and average turnaround takes only two to five days.... case managers can handle more than twice the volume of new applications the company could previously process. (Hammer, 1990).

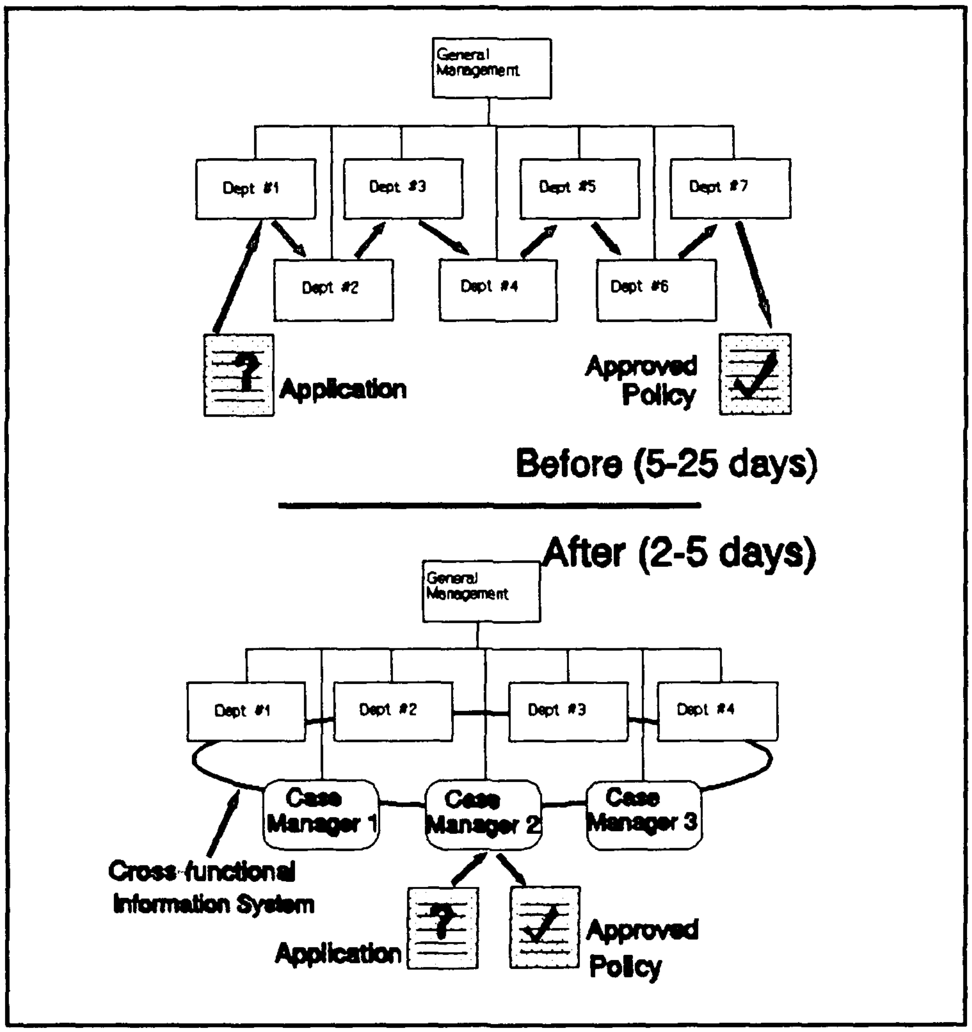

Figure 8: Insurance company example of cross-functional system plus business reengineering.

In the banking example cited earlier, top management limited its application of the cross-functional concept to the information system. They used information technology as a means of enabling better integration between the business units, as in Galbraith's method 6, but retained the existing structure. The life insurance case, on the other hand, is an example of the concept of cross-functionality applied not merely to the information system, but also to the very structure of the organization. The restructured company is sketched in Figure 8. Hammer describes this further step as "business re-engineering:"

> It is time to stop paving the cow paths. Instead of embedding outdated processes in silicon and software, we should "reengineer" our businesses: use the power of modern information technology to radically redesign our business processes in order to achieve dramatic improvements in their performance. (Hammer, 1990).

One can also analyze an organization from the viewpoint of the independent–integrated spectrum of organizational "tightness." On the face of it, one would expect to call a company with a high degree of integration between business units cross-functional, and one with high independence would not be considered cross-functional. Yet, as shown in the case of the bank, *a cross-functional information system can provide the interface that allows independent units to act in a cross-functional manner, despite geographic or functional separation.*

D. STRATEGIC PLANNING FOR CROSS-FUNCTIONAL SYSTEMS

Cross-functionality, whether applied merely to the IS or to the very structure of the organization, will require a level of planning beyond that required for more traditional applications. Yet this does not imply tighter control of application development, nor even more formal and rigid project management disciplines. The planning most needed is top management vision about ways in which the organization can gain a strategic competitive advantage (in the case of the private sector firm) or provide dramatically improved services to the taxpayer (in the case of the public sector agency).

James Wetherbe, at the University of Minnesota's MIS Research Center, has proposed a model for this process that helps management describe the key needs of the organization (Wetherbe, 1984). His four–stage–model, along with a fifth stage added by James Emery (Step 2, architecture; Emery, 1991), is described in the next sections of this chapter and illustrated in Figure 9. The resultant combination is used as the basis for an analysis of the Coast Guard's operational information flow in the next chapter.

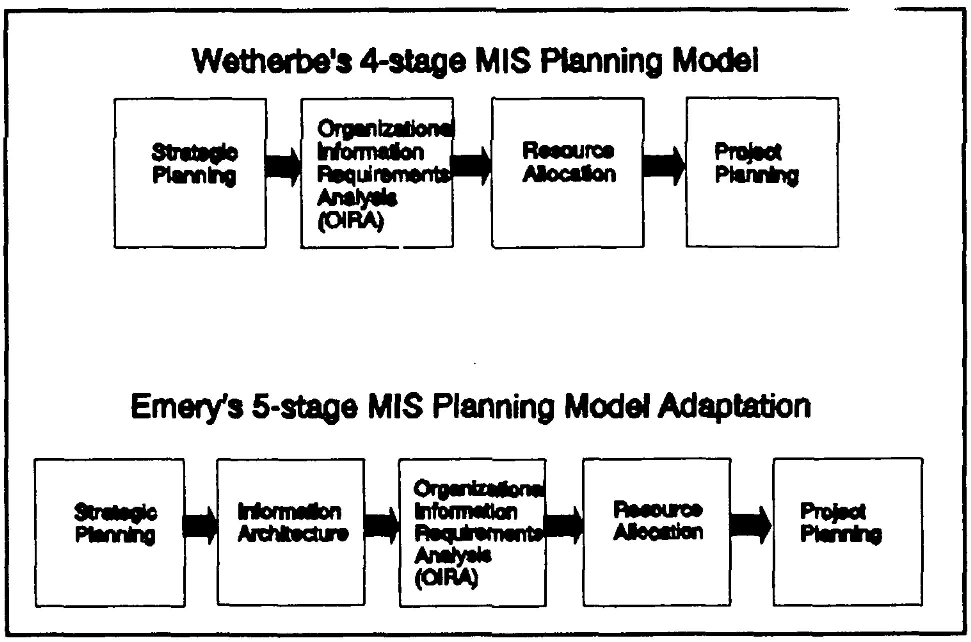

Figure 9: Strategic MIS planning (after Wetherbe, 1984, and Emery, 1991).

The IS plan must of course be linked to the overall business plan. Most organizations have some sort of formal planning process in which top management sets out a vision and broad directional guidelines. Lower level managers then generate more detailed plans for achieving these goals in their own functional areas. There is one potential difference with the IS plan: since information technology offers the potential to redesign the very structure of the organization, strategic IS planning may need to come before the general business plan, and the two will be involved in an iterative process. These relationships are described in Figure 10.

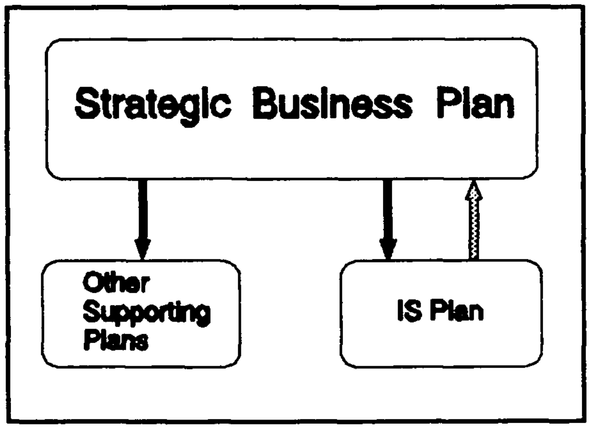

Figure 10: Business plan linkage with IS p lan and other supporting plans.

1. Stage 1: Strategic MIS Planning

The method Wetherbe employs for strategic planning is Strategy Set Transformation (King, 1979). It is designed to provide a direct link to overall organizational strategic planning.

The outputs from the first stage include:

- an accurate perception of the strategic aspirations and directions of the organization;
- a new or revised MIS charter;
- an assessment of the state of the MIS function;

- and a statement of policies, objectives, and strategies for the MIS effort.

This stage is carried out on an infrequent, as-needed basis, perhaps only once in a few years. Later stages will provide the year-to-year detailed plans.

2. Stage 2: Information Architecture

Wetherbe addresses long-range information architecture as a part of his next stage, Organizational Information Requirements Analysis. Emery prefers to break it out as a stage of its own, as outlined herein. (Emery, 1991). The architecture is of critical importance because, properly implemented, it serves a tremendous role as an enabling infrastructure. Just as a transportation system of waterways, railways and highways provide an enabling infrastructure for firms and citizens to carry out free enterprise throughout the nation and world, an ***information architecture*** provides the enabling infrastructure for exploitation of information technology. The three key components of the architecture are:

- An organization-wide telecommunications network;
- A shared database;
- A common user interface.

These components, once established, provide outstanding benefits, both for systems that use them and for future systems development within the organization. First, a robust network allows easy connectivity. Users can communicate with the central database and with each other in a transparent way, independent of time differences and geographical separation.

Second, the common database allows users and management to retrieve information in ways that simply weren't possible before (witness the banking example cited earlier in this chapter). Information from other functional areas, rather than being jealously guarded by individual departments, would be available to enable better decision making in all functional units.

Third, and perhaps most commonly overlooked, is the common user interface. This allows users to gain immediate productivity, without a steep learning curve. This aspect has been one of the weakest points of many systems: program logic may be excellent, but an awkward interface discourages users from spending the time necessary to learn how to use it.

Fourth, and perhaps most important for the organization's long-term information processing needs, is the ease with which new applications can be developed after this enabling infrastructure is in place. A substantial portion of the complexity and cost of new applications goes to the three areas included in the infrastructure -- communications, data management, and interface. By some estimates, the user interface alone counts for 70% of the lines of code in microcomputer applications. This percentage is certainly lower for minicomputer or mainframe applications, but even in this environment the interface accounts for an increasingly large portion of system resources. Given the success of the Macintosh interface described in the previous section, it is arguable that the interface on mainframe applications *should* account for a large portion of complexity. At any rate, if these services are provided by the infrastructure, developers are free to concentrate on program logic, allowing them to deliver systems much more quickly and at substantially lower cost.

3. Stage 3: Organizational Information Requirements Analysis

This stage involves a macro-level analysis of the information needed to support the strategic plan. It should not be confused with the requirements analysis for a specific application project, which includes such detail as report formats and display design. Rather, it constitutes a statement of the key information needed in various parts of the organization, its sources and sinks. Identifying cross-functional information flows (and potential ones) is of special importance here. This stage is repeated annually during the planning cycle.

4. Stage 4: Resource Allocation

It is difficult to allocate scarce "resources among competing organizational units," especially if the "portfolio of potential applications does not fit into an overall organizational plan." (Wetherbe, 1984). The goal of this stage, therefore, is to carry out resource allocation in a rational way, based on the foregoing, higher level plans. Wetherbe lists several well-known methods for allocating resources in a systematic way: return on investment (ROI), zero-based budgeting (ZBB), and chargeout. Each of these provides a structured decision making methodology for prioritizing individual application development projects, and allocating fiscal and personnel resources. Each is also based on estimating the monetary value of the costs and benefits associated with a project. However, estimating costs and benefits of information systems is notoriously difficult, so another method is proposed.

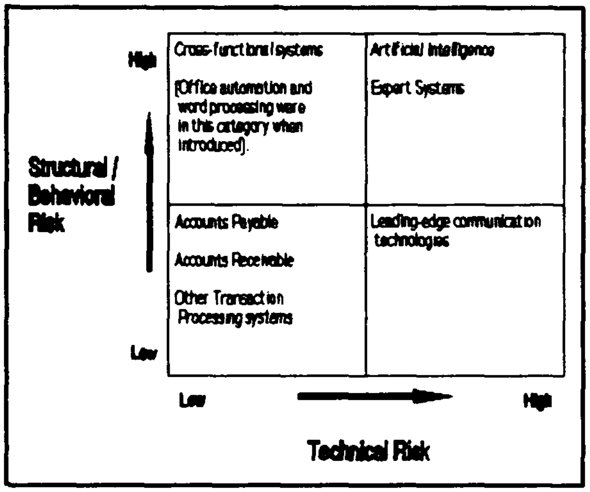

Figure 11: McFarlan's risk assessment model (McFarlan, 1982).

A method not included in Wetherbe's work, but which can provide a valuable analysis of projects based on their respective risks, is a model proposed by McFarlan, McKenney, and Pyburn (1982) of technical risk versus organizational and structural[4] risk. This is worth describing because of its explicit categorization of risks associated with projects; it will be used in the next chapter for analyzing risks of various proposals for Coast Guard systems. The model is depicted in Figure 11. The vertical axis represents organizational and structural risks, and the horizontal axis technical risk. Examples of systems are placed in the approporiate quadrants.

5. Stage 5: Project Planning

The final stage is concerned with developing individual systems on time and within budget. Techniques for this stage include the traditional system development process and various competing methods. Some tools that help manage the project include

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[4]Organizational and structural risk involves resistance to change, political ramifications of the information flow in the organization, and the power represented in control of information. All these combine to form a very subtle, yet complex and deeply rooted set of factors to consider in this regard.

PERT, Gantt charts, and Milestones. A great deal of work is being done on minimizing problems of system development, and there are significant developments being made. The interested reader will find several articles and books devoted to this topic in the Bibliography.

E. SUMMARY

The concept of cross-functionality offers significant benefits to organizations. It is primarily aimed at increasing the ability of the organization to process information. The organization can achieve gains by exploiting this improved information flow within existing structures, or can use the technology as a driving force for business reengineering within the organization.

V. A CROSS-FUNCTIONAL OPERATIONS INFORMATION SYSTEM

This chapter proposes a Coast Guard cross-functional *Operations Information System (OIS)*, built on the theoretical foundation of Chapter IV. The primary focus is on stage 2, the information architecture, and stage 3, the organizational information requirements analysis. A robust information architecture offers great benefits by increasing the availability of information to those who need it, and at the same time decreasing the complexity involved in developing new systems. By analyzing organizational information requirements, it is possible to reengineer the flow of operational information in the Coast Guard, dramatically improving information availability.

The proposal is followed by an anecdotal description of an incident using the present information flow, contrasted with a description of an incident using the envisioned information flow.

A. STAGE 1: STRATEGIC MIS PLANNING

This stage provides the linkage between the strategic organizational plan and the information systems function. This has already been performed by senior management, as discussed in Chapter II. The results of this linkage are framed in the terms of this model below:

- Strategic aspirations and directions of the organization are taken from the Commandant's Strategic Agenda (COMDTINST 16000.21, 21 Sep 90). They are to prevent loss of life, damage to property, and damage to the environment; and to promote safe navigation on the nation's waterways and by vessels of this nation throughout the world.

- The charter specific to MIS in the Strategic Agenda is "to increase efficiency and enhance capability through Information Resource Management." (COMDTINST 16000.21, 21 Sep 90).

- A general guideline which has significant application in the MIS arena is: "Acquire standardized equipment which improves interoperability with other agencies and is fully supportable within Coast Guard or other federal government resources." (COMDTINST 16000.21, 21 Sep 90).

- The state of the MIS function is discussed at length in Chapter III of this thesis. To summarize, there are on the order of 100 separate information systems in use in the Coast Guard, with almost none sharing a common database. There is some use of common communication networks, and improvements are being made. There is almost no commonality among user interfaces. Several major systems are undergoing significant enhancements, and a concerted effort is being made to encourage cross-functionality in those efforts.

- Commandant Instruction 5230.41, Information Resources Management, describes policies, objectives, and strategies which guide the MIS effort. Those are listed in Chapter II.

The sum of the guidance in these policies is clear: the Coast Guard is dedicated to improving its effectiveness through better use of information. There is a mandate to move toward cross-functional systems.

B. STAGE 2: INFORMATION ARCHITECTURE

The enabling role of the information architecture cannot be overstated. With a solid infrastructure as foundation, development of individual systems becomes much simpler. The availability of a common network and user interface mean that developers will not have to expend significant resources on those components, but simply implement the existing infrastructure components in the new system. The common database is the most demanding of the three infrastructure components: not only must the initial database be planned carefully, but subsequent addition of new systems will require careful data modelling to fit the database schema.

1. Telecommunications Network

The Hybrid Data Network (HDN) is the Coast Guard's shore-based telecommunications network. It presently provides dedicated or virtual dedicated interconnection to most major shore units, and will expand to serve all shore units with at least dial-up access by 1992. It has been implemented as the transport mechanism for SARMIS and MSIS.

In order to provide connectivity with mobile units, the HDN must be augmented by establishing radio-based networks that connect with the HDN at key nodes, such as Communication Stations and Group Communications Centers. Several technological options for this are being explored, but none has been selected for deployment yet.

HDN traffic should be prioritized, much as AUTODIN traffic is sorted by four classes of precedence. Time-critical traffic, such as information to support board/no-board decisions in law enforcement cases, would preempt most other types.

In order to support the improved information flow that will be proposed, the radio network will need to support transmission of small bursts of time-critical data at sporadic intervals. This requirement points to packet-switching as the solution, and meshes well with the HDN since it uses the X.25 packet transmission scheme.

2. Common Database

This component of the information architecture is less well developed, but it has received some attention. First, the Coast Guard uses Federal Information Processing Standards, which require database management systems that support the SQL standard. (FIPS PUB 127). Program managers developing new applications are encouraged to use either Progress™ or Oracle™ as the DBMS, by including these two products in the Standard Workstation contract for ease of procurement. Use of any DBMS, especially a common one, will be a vast improvement over the reliance of most current systems on file processing. Second, the Coast Guard has completed a set of Data Element Naming Conventions (DENC), designed to provide a foundation for achieving greater homogeneity between databases in future developments.

Developing the common database, while certainly not a simple task, need not be considered impossibly complex. From a high-level point of view, there are only a few distinct objects about which the Coast Guard tracks information: vessels, people, and various types of incidents or characteristics involving them (law enforcement boarding, SAR case, license number, etc.). With a concerted effort to achieve commonality, and strict application of the the Data Element Naming Conventions, a shared database can be created and new systems can be built to take advantage of it.

To illustrate this point, consider the cross-functional prototype system described in Appendix B. That system illustrates two things:

- That cross-functional systems for the Coast Guard are technically quite feasible. This is evidenced by the limited resources that went into the project. Only about 150 hours of effort (one person-month), from two people with no prior formal experience in database, produced a working microcomputer-based prototype system. It is certainly not a production-quality system, but if such a limited effort can produce a cross-functional system, surely a professional effort can yield effective operational systems.

- That there is a large degree of redundancy of data across the SAR and ELT mission areas. The tables below summarize the data elements found to be common to both mission areas in this prototype.[5]

TABLE 4: REDUNDANCY SUMMARY.

Data Element Type:	Number of Items:	Percent of Total:
SAR	10	7.6
ELT	19	14.4
Common	103	78.0

Tables 4 and 5 summarize the data redundancy found between the SAR Unit Case Folder and the Report of Boarding. Most costly in terms of time and frustration is the fact that field level personnel have to key in the same data to several systems. Also, the Coast Guard pays a heavy toll for the inability to correlate information contained in the independent systems. Finally, there are the problems of data inconsistency across applications and of redundant mass storage at computing facilities.

[5] A caveat is necessary: the data requirements for this project were not taken from SARMIS and SIMS/ELT, but from the less detailed SAR Unit Case Folder (form CG-16130) and Report of Boarding (form CG-4100). The data requirements for the two computerized systems would undoubtedly show less redundancy, but the concept is valid.

At first thought, it seems incredible that nearly 80% of the data in the two systems is the same. However, when one thinks about the type of information the Coast Guard collects in terms of data objects, the reason for the overlap becomes clear. The Coast Guard only collects data about a limited number of real-world objects (people, boats, airplanes, etc), yet we collect it in several independent systems that were developed as stovepipes to support vertically-oriented functional program management. Further, it should be noted that this comparison reflects only two systems. If it had included others, it would likely have found a few more distinct data fields but a large number of common ones.

TABLE 5: OBJECT DETAILS.

Object:	Data Elements:	# of Tables:
Incident	24	3
Weather	20	1
Person	25	2
Vessel	34	1
SAR Case	10	2
Boarding	19	4
Total	132	13

Appendix B describes the real-world objects that must be represented in a cross-functional database such as this, and depicts their transformation into the relations and relationships of the database schema.

3. Common User Interface

In this arena, there is great room for improvement, as described in Chapter III. In one positive move, Unisys, the CGSW vendor, has initiated two efforts to bring improved interfaces to BTOS. First, the company is implementing an Applications Programming Interface (API) called XVT (Extensible Virtual Terminal). Applications written to XVT can be ported to any of several graphical operating environments, including Macintosh, Presentation Manager, Motif, and Windows. It has distributed development toolkits to firms who write software for the BTOS environment, and the first of those new applications have been released. Second, the company plans to support Microsoft's Presentation Manager™ in future BTOS releases.

These standards will provide applications with a similar "look and feel." If well implemented, they will also provide the ease of learning and use that was described in Chapter IV. These will dramatically decrease the time spent on training to use the systems, and increase the range of functionality available to users.

C. STAGE 3: ORGANIZATIONAL INFORMATION REQUIREMENTS ANALYSIS

In this stage, a macro-level analysis of information flows, along with sources and sinks, is conducted. It focuses on key information needed in various parts of the organization, and its sources and sinks. Identifying cross-functional information flows (and potential ones) is of special importance.

The analysis begins with a deceptively simple question: why transfer information from one place to another in the first place? Before analyzing present information flows and proposing another set of flows, it is important to establish the reason for doing so. The answer is that *in order to maximize decision making effectiveness service-wide, the right information must be available to the right person at the right time.* The decision to be made may concern real-time command and control of a particular case, or it may concern long-range planning at headquarters. But at the root of our information collection and transfer is the need to support improved decision making.

1. Present Information Flow

Simplified diagrams of the existing information flow are presented for the Search and Rescue, Law Enforcement, and Marine Safety mission areas in Figures 12 through 14. For the first two, information flows from its source at the field unit to various sinks, frequently stopping at intervening levels for review and aggregation. The fastest reports, used for tactical command and control, are by voice, radioed to a shore site and then relayed by telephone up the chain of command as far as their urgency dictates they need go. Shortly after the incident is completed, the next set of reports go out; these are by message, also to the operational chain of command. They provide hard copy documentation of the incident, and are reviewed for proper handling of the current incident, analyzed for tactical planning, and archived for legal reference. Finally, the last set of reports go into computer databases, providing program managers with statistical summaries for long-range trend analysis, large-scale planning, and the like.

The information flow for the Abstract of Operations is also depicted (Figure 15). In many ways it constitutes a follow-on report to the other systems, but it is worth mentioning separately. The system epitomizes the argument for cross-functional systems, and represents their ultimate goal. These reports have their source at the unit, and their sink at headquarters. They are highly condensed cross-functional aggregates, and the information from which they are abstracted has almost all been typed into the several different systems in some form or another. Yet no mechanism for retrieving information

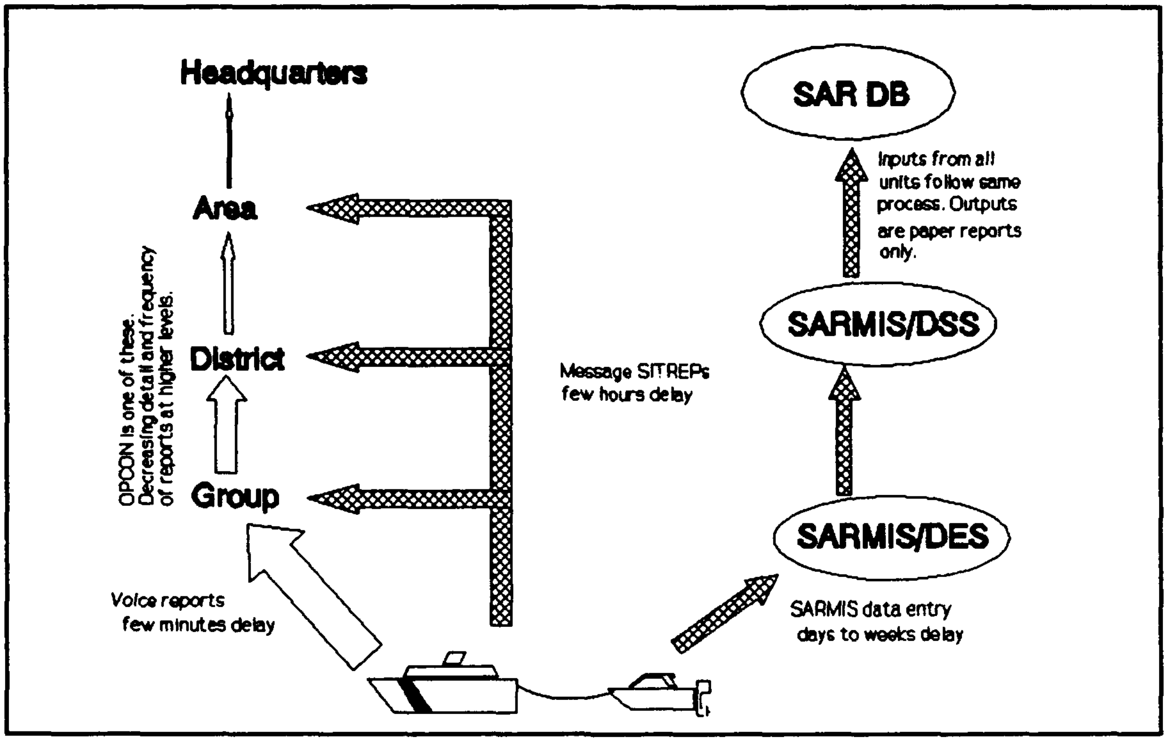

Figure 12: SAR mission area information flow, present day.

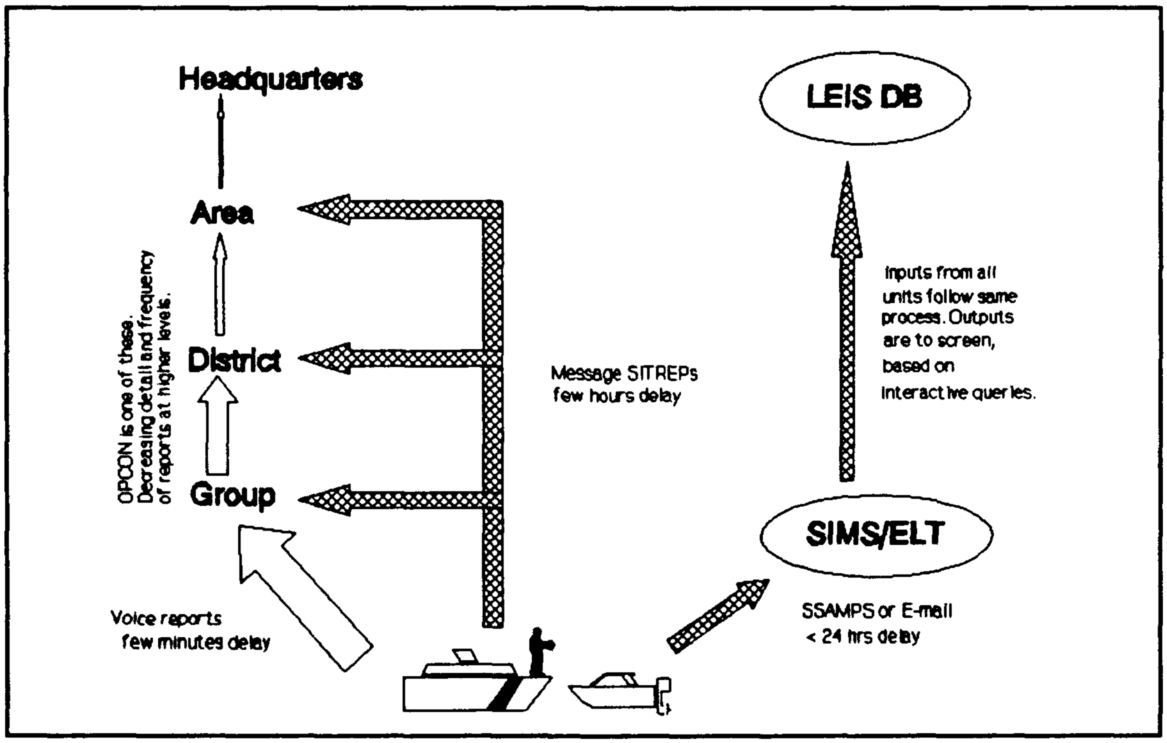

Figure 13: ELT mission area information flow, present day.

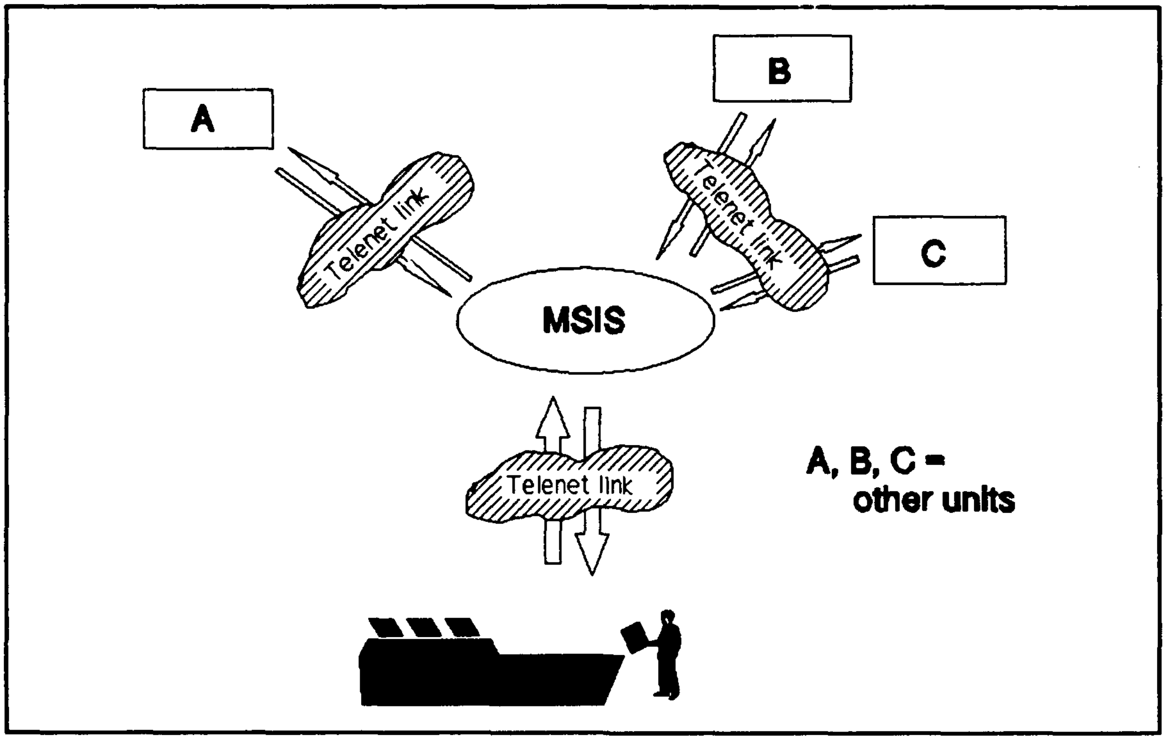

Figure 14: Marine Safety mission area information flow, present day.

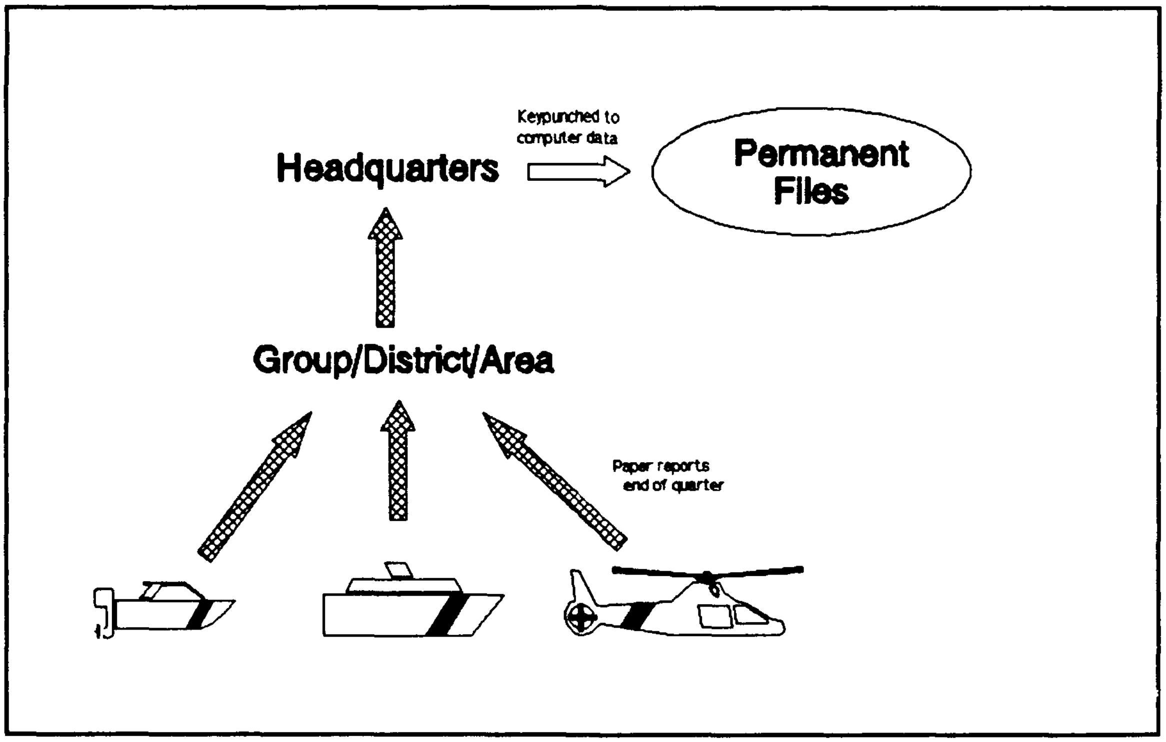

Figure 15: Abstract of Operations information flow, present day.

for this report from the independent systems exists, and so field units are required to consolidate the data manually and submit it on paper.

Contrast the SAR and ELT information flow with that depicted for Marine Safety. In the latter case, information is entered just once, interactively, into a central database. From there, it is available nearly immediately to any authorized user, who may query the database to get just the information needed. Timeliness and information availability are greatly enhanced. The field unit is only considered an information source once: at the time it updates the central database. From then on, the central database becomes the source of almost all future information flows. (This is admittedly an oversimplification -- Marine Safety units do complete and file paper reports that are not generated by MSIS, and they also send message reports of their activities to addressees that do not have access to MSIS. However, the general information flow is much more streamlined for the marine safety mission area than for the others).

The two different information flows result in vastly different information processing workloads for the field units. A Marine Safety unit submits a single report of an incident, either while the incident is ongoing or immediately afterwards. A unit conducting Search and Rescue or Law Enforcement, on the other hand, submits reports as the incident is ongoing, then message reports, and finally database entries, all to different information sinks and at different times. The information in all three is largely similar, but is in different formats and data standards (e.g., no commonality in date formats: MMDDYY, DDMMYY, military date-time group, etc).

a. SITREPS

SITREPS are required by most operational commanders at four hour intervals, or "as the situation warrants." Yet even if sent at Operational Immediate priority, these messages generally spend most of an hour in transit to the commander, so some information may be five hours old. A SITREP is basically a summary of *events* to date regarding a particular case. Operating units record these events in logbooks or on scrap paper as they happen, then draft a report that summarizes them for the commander every few hours.

b. Information System Entries

Data is entered into the information system after the fact (except for some cases of MSIS). It may be entered on the same day (SIMS/ELT), or perhaps several days or weeks later (SARMIS). But regardless of the actual time delay, it is keyed in separately from the incident, with no means for capture while the incident is ongoing. The information in these reports is largely the same as that in the SITREPs the unit sent out during the incident; although it may be in slightly different form, it too consists of a summary of the individual *events* that constituted the incident.

2. Reengineering the Information Flow

Information technology now allows us to dramatically improve the situation. By reengineering the information flows, we can significantly ease unit workloads dedicated to information processing, provide better and more timely information to the commander, increase availability of information to other users, and provide crucial intelligence information to the field unit.

a. *Event-based reporting*

The basis for the new information flow is a redefinition of the basic unit of information. The SITREP has serious flaws as a basic unit, because of the inherent delay and the inability to manipulate the information. The key element of improving the information flow is already in place, in the ***event lines*** of SEER and SIMS/ELT. Simply define the individual events that heretofore comprised the SITREPs as elemental information units. Rather than reporting compilations of information, units can report things as they are happening, in the smallest meaningful granularity.

What attributes make SEER events so suitable as the basis of reporting? To clearly understand, it is useful to consider information units that are too small and too large, respectively. For instance, an event might be described by several data fields which convey the fact that "Our unit is at position PP-PP.P, at time TTTT, and has sighted the vessel described as follows: (*name, document number, etc*)." All these data elements must be present in order for the information to be meaningful.

Smaller information units, such as merely the name of a vessel sighted or the position in which it happens to be at that time, would prove to be largely meaningless, because they fail to provide the needed ***context***.

Larger information units would have greater utility, but would suffer from too great a time delay: while it would be nice to know that the vessel in question proved to have illegal drugs aboard, that fact will not become known for an hour or more after the initial sighting of the vessel. Delaying the sighting report for greater completeness would render the earlier information valueless for real-time command and control. That is the situation the Coast Guard finds itelf in today, by using compilations such as SITREPs to summarize incidents. Even an improvement such as sortie reports, where information would flow from the unit in an integrated, cross-functional report that describes every event that occurred during a particular sortie would suffer from this drawback.

Figures 16 and 17 graphically depict the proposed information flow, and one possible phased approach to achieving it. In phase 1, information would continue to flow from the unit to the existing stovepipe systems. OIS-1 could then query the heterogeneous systems, serving as a single source of information for non-real time information needs. This phase should include a homogeneous "front end" to the system, which would present a single face to the field user who is inputting data; it would collect each piece of information just once, and route it to the appropriate system automatically.

In phase 2, the central database itself would become integrated, along with communications, and all users would conduct transactions interactively and directly.

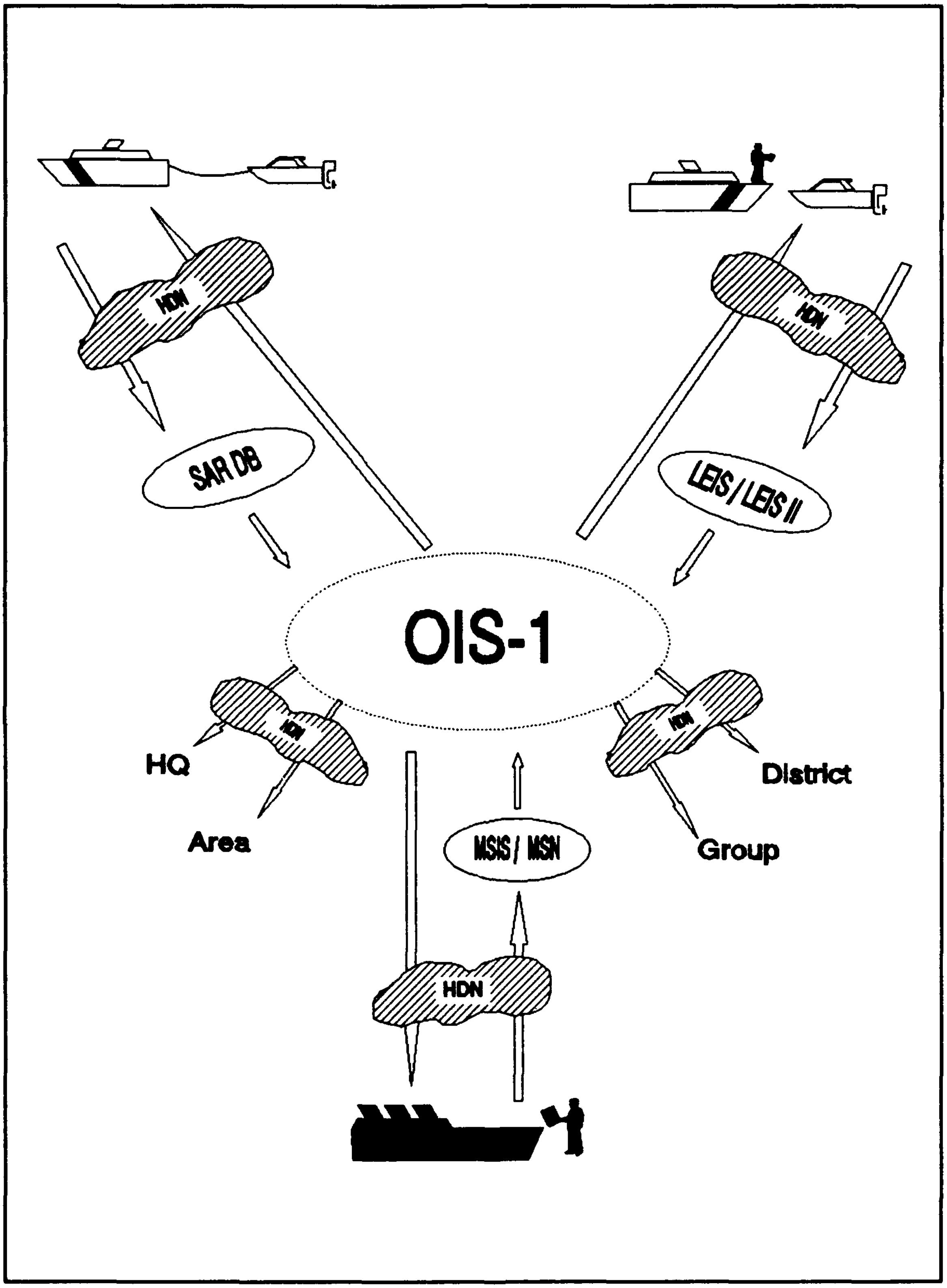

Figure 16: OIS information flow, phase 1.

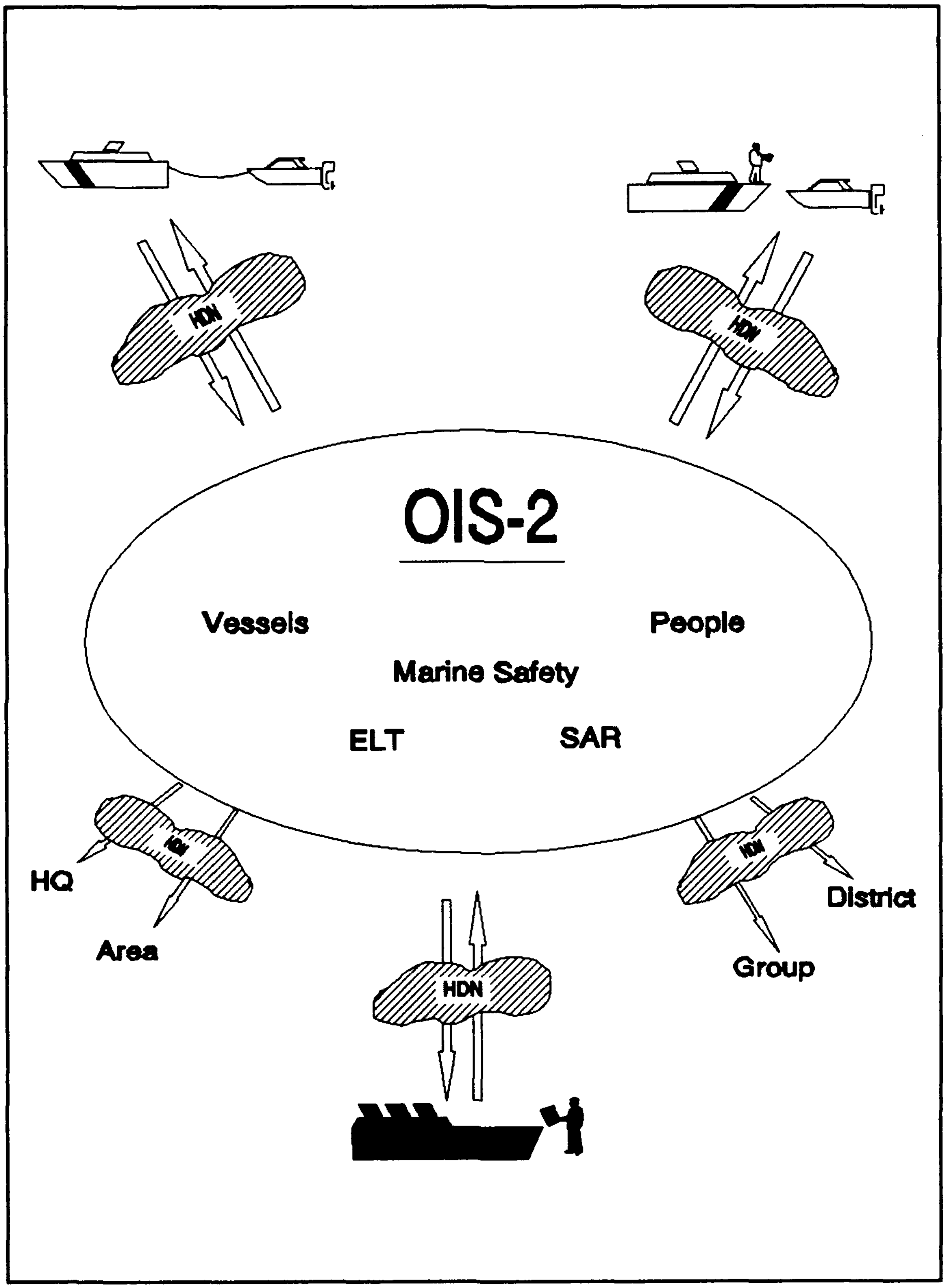

Figure 17: OIS information flow, phase 2.

D. STAGE 4: RESOURCE ALLOCATION

The goal of this stage is to allocate scarce resources between competing proposals in a rational way, based on the foregoing higher level plans and some set of comparative measures. The traditional measure, cost-benefit analysis, is of questionable worth for evaluating IS projects, because of the great uncertainties associated with both costs and benefits of information systems. As one alternative, Chapter IV described McFarlan's risk analysis model; that is presented again here, this time describing Coast Guard systems. Another way of thinking about these systems is developed in Chapter VI. It proposes that motivating cross-functionality and a common information architecture can best be done by drawing an analogy to public goods in classical microeconomic theory.

It is felt that existing Coast Guard systems are low risk, technologically and structurally (see Figure 18). However, when systems are combined in a cross-functional manner, two things happen:

- First, because of the increased size and complexity of the integrated system over the standalones, the technical risk increases somewhat. However, the scope of the proposed OIS is nowhere near the limits of current system development capabilities, so it is not far out along the axis.

- Second, because of the implications which the integrated system has for change in the organization, the structural/behavioral risk increases dramatically. A large part of this risk is the reluctance of those who presently control certain information to share it, since information entails power within the organization.

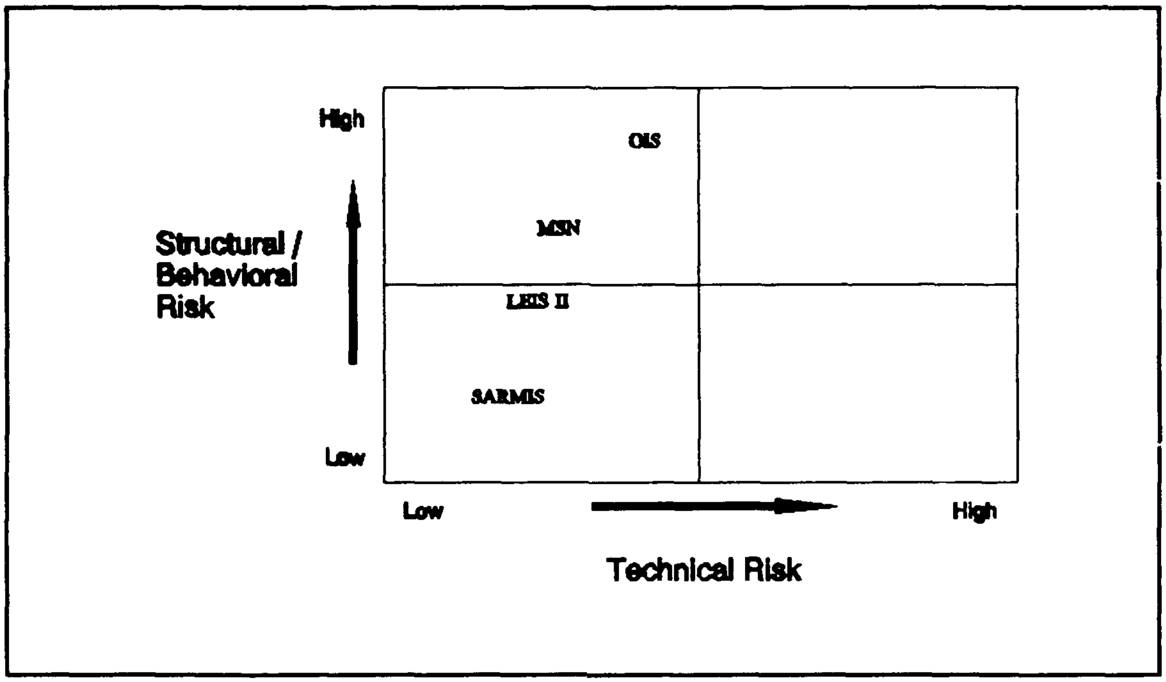

Figure 18: Coast Guard systems analyzed using McFarlan's risk assessment model.

Even for the scope of the proposed OIS, it is felt that the organizational/structural risk far outweighs the technical risk (see Figure 18). Relational database theory and technology are at a level where associating data elements with one another in a meaningful, flexible way through the use of a DBMS is relatively routine, and eminently achievable. This is not to say that the technical risks are nil; the system is fairly complex, and requires careful thought and planning to build the database schema in a useful, flexible way. But the higher risks are certainly along the structural/behavioral/political axis of McFarlan's model.

E. STAGE 5: PROJECT PLANNING

OIS is envisioned as a system of systems, wherein program managers continue to develop individual systems for their mission areas in a relatively decentralized fashion. In this way, they will ensure that the system meets their needs, have the ability to make changes, and other benefits associated with decentralization. However, systems will no longer be developed "in a vacuum," where the program manager builds all the pieces of the system and controls it in its entirety. Rather, each system will be based on the common infrastructure, and reap the benefits of less development time devoted to those items.

Incorporating the common network and user interface in new applications should be almost effortless. Implementing the common database would not be quite as simple; new systems must be carefully fitted to the existing database, employing existing relations where possible, and melding new relations and relationships into the schema as well. The total cost of the new system, however, would be significantly lower than if it had been developed entirely on its own.

F. AN ANECDOTAL DESCRIPTION

The benefits to be realized from an integrated Operations Information System may become even more obvious if described anecdotally. The next two subsections depicting the existing and envisioned information flows in a hypothetical scenario and the ways in which Coast Guard decision makers at all levels will be aided by availability of better information.

1. Present Information Flow

Coast Guard units on law enforcement patrols routinely sight and identify hundreds of vessels. They choose to board a few of these, ensuring compliance with many federal laws -- e.g., those governing boating safety and documentation, fisheries, smuggling, and illegal immigration. The decision on whether or not to board a particular boat is based on several factors, including the number and description of other vessels nearby, course and speed the boat has been pursuing, and apparent intentions. While in no way definite, these factors act as very general indicators of whether or not a boat may be in violation of any of the afore-mentioned laws, and serve as bases for decision making. Other, much more informative, factors in the decision include intelligence reports, registration information, recent sighting reports confirming a trackline along a known smuggling route, and more. These are available, but take significant time and effort to retrieve: a voice radio call to a Coast Guard shore site, then several telephone calls and computer inquiries against remote databases, and a return radio call to the patrolling unit. This process takes the better part of an hour under the best of circumstances; if the shore site is busy, the information may not be available at all. And if more than a few queries per day come in, the shore site is overloaded.

The result of this torturous information flow is that when a patrol unit decides to board, it rarely does so on the basis of information gleaned beforehand from shoreside databases. The boarding party goes across without knowing the registered owner or any intelligence about the vessel. People on board may have outstanding arrest warrants, or even be described as "armed and dangerous," but that information rarely gets to the patrol unit before they go aboard. It would be much safer to know such things ahead of time, but current procedures and technology do not allow it.

2. Proposed Information Flow: Event-based Reporting

Now let us consider the same scenario, but with an event-based OIS in place. A patrolling cutter sights a vessel, triggering a real-time OIS information flow. Cutter personnel record the vessel's identifying characteristics (name, document number, length, color, etc) in their local CGSW. The shipboard system immediately sends this event report out over its dedicated HDN link to the OIS. Since the event was an identification, it also automatically addresses it to several other recipients, including the operational commander and "information" addressees specified by the unit commander. The OIS, recognizing the event report as an identification, automatically updates the database, and also issues a query against it. It retrieves a "tactical decision history" of that vessel -- recent sightings, boardings, violations, and intelligence. It also produces a list of people associated with the boat: owner, operator, and others, along with any outstanding warrants or intelligence reports. This information is returned to the patrolling cutter within seconds after the identification information was sent out, and a copy forwarded to the operational commander. The cutter CO can then make an informed decision about whether to board the vessel in question, and the information contained in the identification event is available to all parties who need it in near real time.

Information no longer flows up the chain of command, stopping along the way for review and aggregation. Instead, it becomes immediately available to all parties who need it. Each information user can issue queries, or design entire applications, to aggregate the OIS data into the appropriate granularity for the task at hand.

G. THE USER INTERFACE REVISITED

The OIS user interface should rely heavily on integrated sensors and flexible input devices. Integrated sensors offer the ability to completely avoid human data entry, by automating the collection of certain frequently used data. An interface based on National Marine Electronics Association (NMEA) standards would link a shipboard system directly to the integrated navigation packages for collection of position information. Similar possibilities exist for weather sensors.

Flexible input devices will be key components of the user interface. The mere act of writing can be a challenge aboard mobile units, especially small cutters or boats. Recognizing this, many units have stopped trying to write, and begun using tape recorders to capture radio communications and other significant events for later transfer to the ship's log. Incorporating voice recognition processors would allow hands-off, natural interaction with the information system. Currently available off-the-shelf products allow discrete speech recognition with excellent accuracy for a few hundred dollars.

There will be some difficulty in implementing this technology, because of high background noise in many mobile environments. In cockpits and on coxswain flats, loud and varying engine and wind noises are the rule. However, by using helmet-mounted microphones these barriers can be overcome. Variability of speech patterns from one individual to another hampers current generation systems, but is easily overcome by using a system that is trained by the individual who will be operating it.

In some cases, it is not possible to avoid the need to write or key in data. For these situations, the Coast Guard should incorporate pen-based computers, which will be available off-the-shelf this year. The first generation of these are especially well-suited to form fill-in, such as the Coast Guard would be interested in.

H. THE OVERALL VIEW OF OIS

A key advantage to developing a system such as this would be its reliance on the organization-wide information architecture to the greatest extent possible. OIS would consist of several applications sharing a common database, communicating via a common network, and presenting a single face to the user through a standard user interface. Systems that are presently independent would be migrated to this shared environment, and become modular components of the system.

By developing the system in this fashion, it remains relatively simple to upgrade or replace an application module. The remainder of the system would be undisturbed.

VI. MOTIVATING SYSTEM DEVELOPMENT: SPECIAL CONSIDERATIONS

A robust information architecture, and development of cross-functional systems that rely on such an architecture, are critically important to the organization's effective use of information. Yet motivating the development of these specialized projects is not easily done in an atmosphere where program managers develop systems independently of each other, and compete for budget dollars. This chapter will be devoted to further analysis of the special concerns surrounding motivation of cross-functional systems and the information architecture. It will draw distinctions between the information architecture, cross-functional systems, and application systems, and discuss the ramifications these distinctions have for development of the various classes of systems.

The analysis here will be framed largely in terms of the degree of centralization versus decentralization of systems, and the proposed solutions will lean toward economic motivation of system developers. To this end, those topics are reviewed first.

A. CENTRALIZATION VERSUS DECENTRALIZATION

The debate over centralization versus decentralization in organizations is much wider than just information systems. Of course, the debate existed before computers did, and the issues at stake have changed little. The important questions regard what type of organizational structure, and information systems structure, are best for the smooth functioning of each organization. The remainder of this section recaps the typical arguments in favor of centralization and decentralization, relying heavily on Wetherbe (1984, pp. 297–300).

1. Arguments in Favor of Decentralization

a. Proximity to Users

If systems are developed by personnel close to the problem, they will tend to be much more likely to produce workable solutions. As systems grow more and more complex, it becomes increasingly important to have close interaction between users and developers. Only in this way will the resulting systems meet users' needs. It is very difficult to specify requirements for a complex information system in advance -- users are not familiar enough with what technology can do for them, and developers (especially if they are remote) are not familiar enough with the problem. By decreasing the isolation, one can improve the resultant system.

b. Speed of Response

Decentralized computer hardware and support personnel can respond more quickly to user needs than centralized resources.

c. Profit and Loss Responsibility

The costs of decentralized resources can be easily charged to the responsible departments, making them more sensitive to the tradeoffs of cost versus value derived from the system. The departments will be much more prone to weigh requests carefully if they are responsible financially.

2. Arguments in Favor of Centralization

a. Economies of Scale

For very expensive items, it is most cost–effective to use only a few, and centralize them so that the entire organization has access to them. This applies especially to large computer hardware items, and most of all to organization–wide databases. It would be technically possible to keep separate copies of the complete OIS database at several locations, but the cost of doing so would be extreme. Beyond the mere duplication of hardware is the huge problem of maintaining consistency of the distributed databases. It is much more feasible to access a central database, despite telecommunications costs, than to try to maintain a consistent distributed database. Research may change this, but for the foreseeable future, centralized data will be by far the most practical.

b. Limited Personnel Resources

Specialists in any field, including computers and systems, are scarce and expensive resources. By centralizing them, it is possible to achieve a sort of "personnel economy of scale." At the central location, they are more likely to be kept fully occupied than if distributed, so it makes economic sense to keep them there.

c. Organization–wide Consolidation of Information

"Financial and operating data are readily consolidated for reporting and evaluation purposes. Without centralization, consolidation is usually obstructed by incompatibilities of different system design, coding schemes, and data formats."

(Wetherbe, 1984, p. 298). This quote strikes at the heart of the argument for cross-functionality. The Coast Guard should design cross-functional systems, systems that rely on a common architecture. In this way, it is possible to reap the advantages of decentralized development and control and those of centralized information consolidation at the same time.

d. Ease of Control

Centralized resources are easier to control. However, this ease of control is counterbalanced by a tendency to stifle initiative. Wetherbe states the classic argument that "through centralized systems development, uniformity can be achieved." (Wetherbe, 1984, p. 298). But with the advent of client-server or distributed systems, the entire system need not be centralized. By centralizing the bare minimum, the critical information architecture, and adhering to the rapidly developing open standards, it is possible to have uniformity while still achieving the advantages of decentralized system development.

B. PUBLIC GOODS AND SERVICES

The next step in develcping the special distinctions between the information architecture, cross-functional systems, and application systems is to describe what it is that typifies a "public good." The discussion begins with a definition of the limited roles government should take in a marketplace, according to classical microeconomic theory. Later, the environment for systems development in the Coast Guard will be compared to a marketplace for goods and services. In this analogy, program managers are viewed as utility-maximizing individual consumers, and the office of Command, Control, and Communications is viewed as a supervisory authority like the "government" of that theory.

In most instances, of course, a free market society expects government to let the marketplace function on its own. However, there are four cases in which government should become involved:

- To provide a special category of goods and services, normally referred to as public goods.
- To correct imperfections (through regulation).
- To redistribute income (through taxes and subsidies).
- To protect rights of parties. (Gates, 9/18/90)

A classic example of public goods, with room for discussion of the government's other roles, is the public network of roads and bridges. It provides society with a vital ability to transport goods and services. However, this network was not developed by the people and companies who use it. Rather, it was developed by the government (which is regarded here as a monolithic whole, with the different levels of government ignored). The majority of the system was directly funded by the government, and is completely open to public use.

In some cases, individuals or firms choose to build their own roads, especially short, special-purpose links to the public roadway network. This is certainly permitted, even encouraged. However, these private roads must be built according to government standards, and must not be built so as to be illegal. These standards illustrate the regulatory powers of government.

Finally, government may decide that society would benefit from private development of certain roads or connecting thoroughfares, but not feel that they are completely in the interests of the general public. It may then decide to encourage private entities to develop those roads by offering a subsidy. This may be viewed as a cost-sharing arrangement that provides benefits for the private entity and also for society. In economic terms, the government subsidy allows the private entity to "internalize the external benefits" -- since the private entity is doing something that benefits society, society assumes a portion of the costs. Conversely, if a private entity is doing something that costs society, such as polluting the air or creating a noisy environment, government may impose a tax on the entity. The amount of this tax approximates the cost to society of the entity's activity. (Rasmussen and Haworth, 1979, p. 458).

In summary, the government (or some regulatory authority) has several important roles in the marketplace, which will be compared to the roles for a regulatory division within the Coast Guard. These roles are:

- To provide goods and services that benefit society as a whole
- To regulate private economic activity, preventing illegal or immoral acts.
- To help private entities realize rewards for indirect benefits that they create for society, in the form of a subsidy. Conversely, to ensure that indirect costs they impose on society are made real for the private entities, in the form of a tax.

C. DEVELOPING APPLICATION SYSTEMS

Application systems fill special end-user needs, and are frequently best developed in a decentralized fashion. System developers are much closer to the users, so the close coordination that is vital to a successful development effort is much easier. Also, the costs and benefits of an information system proposal are likely to be weighed much more carefully if they are chargeable to the department making the proposal.

The program managers at Coast Guard headquarters are the ideal sponsors of the existing, independent application systems (MSIS, SARMIS, LEIS, etc). They have a more direct interest in the success or failure of their MIS than any other office. They are likely to consider the costs carefully in relation to other program expenditures. And although they are not decentralized geographically, they are significantly more decentralized organizationally than the Information Systems Division, G-TTC.

Considered in terms of the economic marketplace analogy, program managers act largely to maximize their utility for their own programs, with little consideration for the benefits or costs their efforts may have to other programs, nor for the benefits they may be able to receive from other programs. For stovepipe application systems, this situation is acceptable, in fact desirable -- applications are optimized for the good of the programs they serve. However, when systems must become cross-functional, this situation needs massaging in order to provide the best solution.

D. DEVELOPING CROSS-FUNCTIONAL SYSTEMS

The program managers also have a vital interest in any cross-functional system that affects their programs. Each would certainly like to have complete control over such a system, to ensure it meets program needs perfectly. However, by their very nature, cross-functional systems benefit the entire organization, not just a single department. It is difficult or impossible to optimize systems for the good of *both* the whole organization and of individual departments. Therefore, it behooves the organization to devise a mechanism for ensuring cross-functional systems are optimized for the good of the whole, and if necessary be sub-optimized for the individual divisions.

This concept is already recognized by the Coast Guard. Coast Guard IRM Principles clearly state that "individual IRM solutions may be suboptimized for the greater good of the Coast Guard." (COMDTINST 5230.41, 31 May 90, p. 2). Program managers are indeed cooperating on next generation systems development at a level not seen before. However, there is no firmly established mechanism for encouraging them to adhere to this principle, and no means of discouraging them from continuing independent system development should they choose to do so.

The roles of government in the marketplace suggest a solution to this dilemma. Just as government can use subsidies, taxes, and regulation to encourage, discourage or prohibit certain behaviors on the part of utility-maximizing individuals or firms, G-TTC should be empowered to use these mechanisms to foster development of cross-functional systems. The IRM Principles already state the desired result, that systems be built for the good of the whole. But without a mechanism for implementation, a principle may do little for the actual state of affairs. The principle should be embodied in a "regulatory system," requiring optimization for the good of the whole. This kind of control rests with the budgetary process, where G–T has had no authority until recently, and even now only review, not approval. The role of G–T in the budgetary process should be enhanced to provide the necesary mechanism for encouraging cross-functional systems and discouraging stovepipes.

The regulatory system would encourage cross-functional systems by a "carrot and stick" approach, providing subsidies to program managers who develop them and taxing those who do not. The subsidy could involve a direct transfer of funds to the program from a special account established for such a purpose and managed by G–TTC. It could define a certain level of technical or management support from G–TTC. Finally, it could entail some form of lower communication charges for using the Hybrid Data Network, or other parts of the information architecture (below). The "taxes" would be largely the opposite of the possibilities for subsidies.

E. DEVELOPING THE INFORMATION ARCHITECTURE

The information architecture is quite different from application systems. Rather than benefitting one group of end users, the information architecture is a special infrastructure which benefits the entire organization. It is of a magnitude that can benefit from economies of scale by centralizing. And it requires centralized planning and control in order to provide services to all users. A robust information architecture is also likely to be prohibitively expensive for any single system, yet would prove very beneficial to system developers once implemented.

The information architecture is clearly a special case, which should be provided on an organization-wide basis. It should be funded and managed as a public good, an element of society's infrastructure. The Office of Command, Control, and Communications (G-T) should establish standards for the architecture, obtain funding for it, and maintain control over it, providing access to it for all system developers. This approach has several benefits. One of the largest comes from the network externality of economic theory. If a telephone network has access to only a hundred subscribers, it is worth very little to a potential subscriber to join the network because of the limited number of others that can be reached. Yet if the network has a hundred million subscribers, or at least reaches all persons with whom the potential subscriber wants to communicate, it is worth a great deal more. The Hybrid Data Network, as a cornerstone of the Coast Guard's information architecture, should be controlled by a central authority within the agency for the good of the whole organization.

Another benefit from the information architecture is in reduced costs for developers of cross-functional systems, or even stovepipe applications. By relying on existing standards in the area of telecommunications, database, and user interface, developers would be able to dramatically reduce the time and cost required for new systems. It is not at all unreasonable to expect that such development efforts would be less than half as costly as completely independent systems.

Finally, the Coast Guard should formalize an initiative that is growing within G–MIM. That office is developing the contract specifications for the new Marine Safety Network. They hope it can be used as a common contract vehicle for MIS projects by all program managers. This could significantly reduce some of the up–front contracting work, allowing system developers to concentrate more on the system requirements, rather than the mechanics of how to acquire it.

VII. CONCLUSIONS AND RECOMMENDATIONS

Information technology, well implemented, can clearly provide major benefits to the Coast Guard. Existing systems do not provide the organization with a smooth information flow. Cross-functional systems, based on a robust information architecure, will dramatically improve information flow, reduce redundant use of personnel time for data entry, reduce duplication of effort across programs, and improve availability of information to decision makers.

A. CONCLUSIONS

Information does not flow smoothly, but follows a torturous path through the organization. It is frequently not available to employees who could use it to make better decisions for the organization as a whole.

Existing systems suffer from a large degree of overlap and inconsistency in information content, but offer no means for eliminating the overlap or reconciling the inconsistencies. This forces repetitive data entry into separate systems, and increases workload and frustration for field personnel.

Existing systems suffer from poor connectivity and user interfaces, which combine to make it difficult to retrieve information. As a result, decision makers do not get information they should have. Others are forced to spend significant time and effort, both in learning how to retrieve information, and in actually performing the process.

Cross-functional systems offer a means of correcting many of these problems. By improving the flow and availability of information within the organization, they offer opportunities to improve effectiveness of the existing organizational structure by re-designing processes. Further, they offer the opportunity to re-engineer the organization to better serve the public.

B. RECOMMENDATIONS

1. Future Development

The Coast Guard should aggressively pursue its stated policy of developing cross-functional systems. Specifically, it should develop a cross-functional Operations Information System (OIS), as described in Chapter V.

OIS, and other cross-functional systems, should rely on a robust information architecture. This should consist of a common telecommunications network, a common user interface, and a small number of common databases. Development and maintenance of the information architecture should be centralized, as described in Chapter VI.

Application systems should be cross-functional whenever possible, and this should be encouraged as part of the budget process with some form of subsidy, as described in Chapter VI. Similarly, stovepipe systems should be discouraged, through some form of tax. Application systems should be developed and maintained in a decentralized fashion as much as possible. New applications should be implemented in a scheme of phased deliverables, tying into existing cross-functional systems a piece at a time.

2. Existing System Upgrades

Existing applications should be upgraded, because of the long lead time until they can be incorporated into a cross-functional system. However, the upgrades should not disregard the potential for cross-functionality. Rather, upgrades can pave the way for smooth transitions to eventual cross-functional systems. Specific recommendations follow.

a. Data Storage and Retrieval

Transition the data from file processing systems to database management systems. Use one of the Coast Guard's standard DBMS packages, either Progress™ or Oracle™. Rely on the Data Element Naming Conventions when designing the schema for the upgraded database. In this way, transferring the data to a cross-functional database later will be significantly easier.

b. Telecommunications Solutions

Transition from independent telecommunications solutions to the Hybrid Data Network. Build support for the HDN into applications, and hide the task of establishing connections to the central site from the user.

c. User Interface Design

Define a style guide for applications. This should rely on menu-driven interfaces, using the soft-key approach to defining the function keys. Menu structures should be similar, and thus familiar, between applications. Future applications should be written to the XVT API, providing the additional ease of use of a Graphical User

Interface when the end user's workstation supports it. The combination of style guides and GUIs will greatly enhance user's productivity.

Transition from the SARMIS approach, which presents users one question at a time on screen, to something like the SIMS/ELT approach. This presents the user with a form containing logically related data elements, allowing faster data entry and better understanding of how much of the task has been completed.

Build support for integrated sensors and flexible input devices into future applications. The key is to integrate information systems into the operating units' work patterns as closely as possible, so that their attention may be focused on conducting operations rather than on gathering or reporting information in support of operations.

d. Distributed Processing

Employ the processing power of the Standard Workstation to provide the user interface, establish connections, and maintain local databases. Avoid applications that treat the CGSW as a dumb terminal.

APPENDIX A: U. S. COAST GUARD ORGANIZATION

The following pages describe organizational relationships within and affecting the Coast Guard. Figure 19 shows the Department of Transportation organization. Figure 20 shows the operational chain of command in the Coast Guard. Figure 21 shows the staff organization at Coast Guard Headquarters.

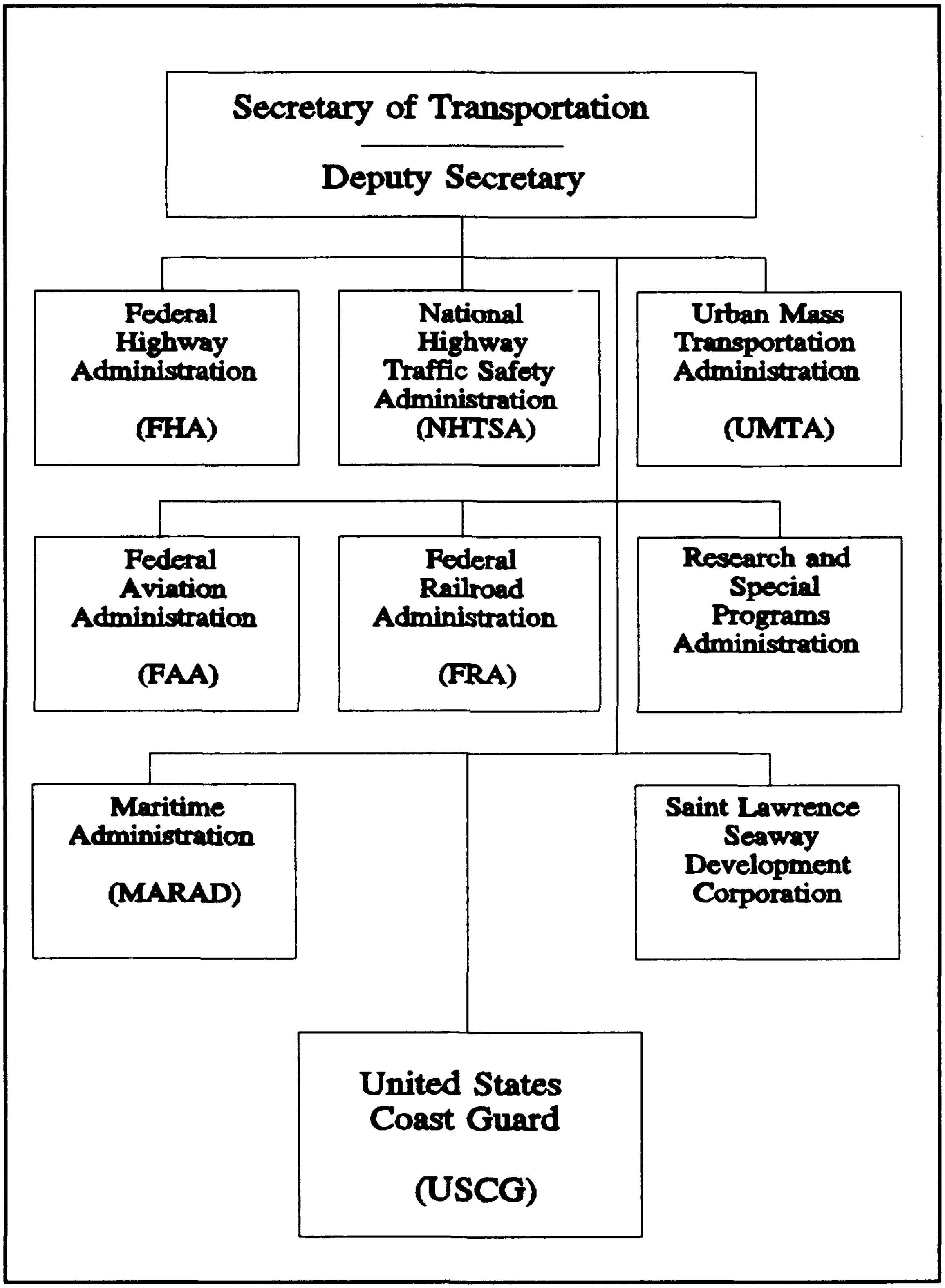

Figure 19: Department of Transportation organization.

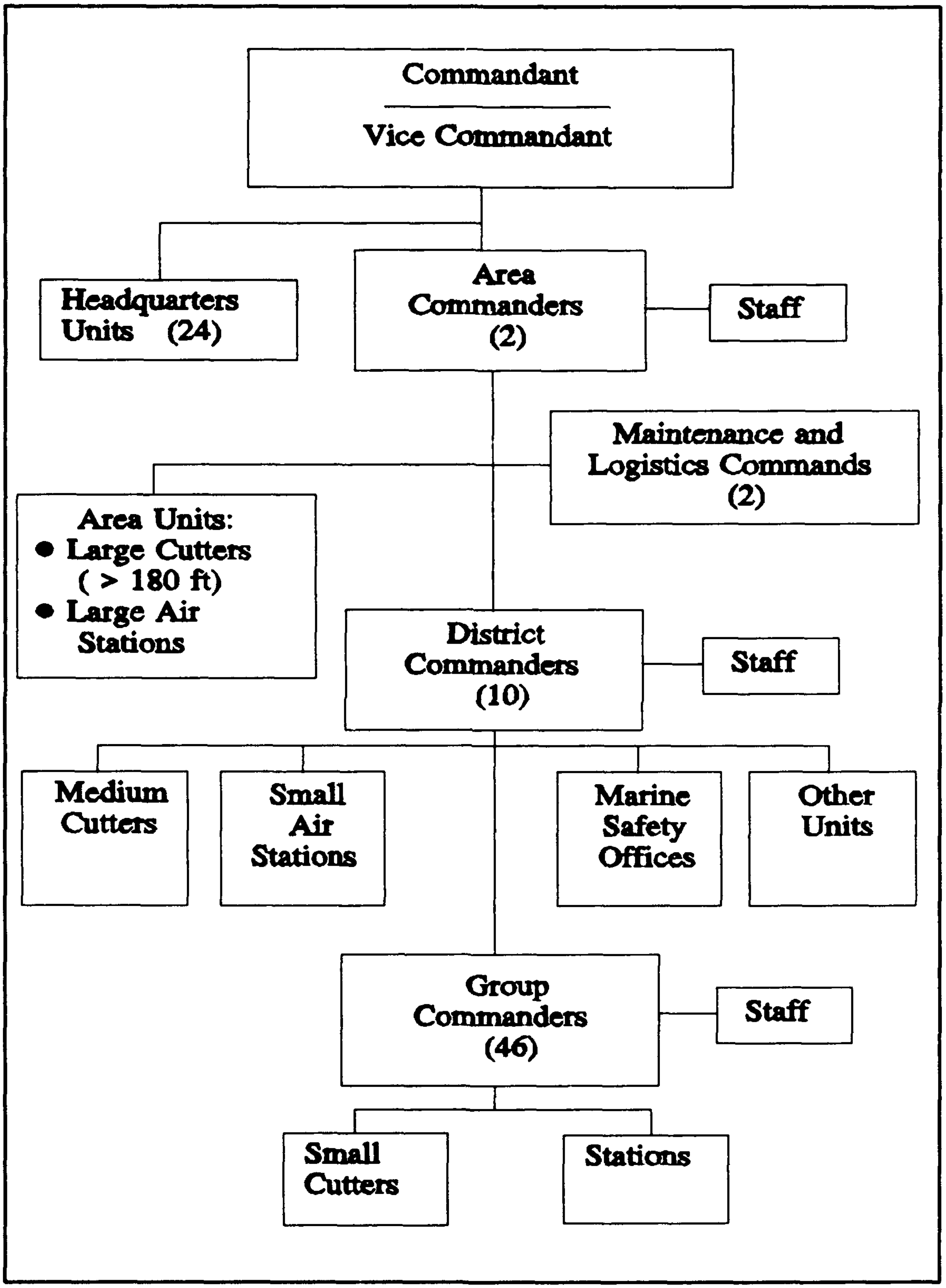

Figure 20: U. S. Coast Guard organization.

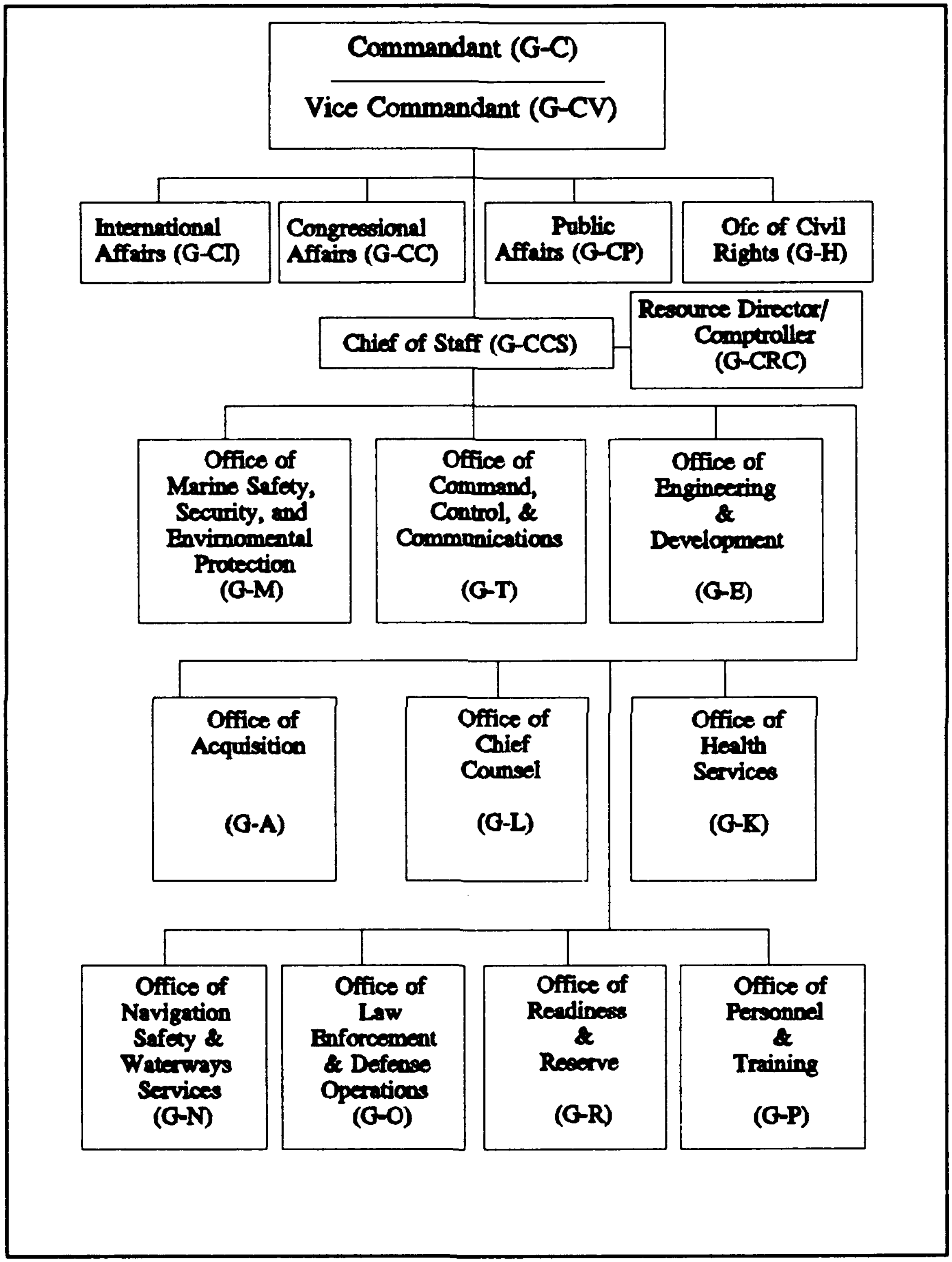

Figure 21: Coast Guard Headquarters Organization.

APPENDIX B: CROSS-FUNCTIONAL DATABASE PROTOTYPE

This Appendix contains a summary of a database project done by the author and another student (Glidden and Marsh, Dec 90). It was designed as a prototype cross-functional system to support two of the Coast Guard's missions, Search and Rescue (SAR) and Enforcement of Laws and Treaties (ELT).

Tables 13 and 14 in Chapter VI describe the 78% overlap between the information in the Report of Boarding, form CG-4100, and the SAR Unit Case Folder, form CG-16130. At first thought, it is hard to believe that nearly 80% of the data in the two systems is the same. However, when one thinks about the type of information the Coast Guard collects in terms of data objects, the reason for the overlap becomes clear. This list describes the objects:

INCIDENT	This is the main object in this prototype. The bottom line is that the Coast Guard collects all this information from field units and stores it in a central computer *because something happened.* It happened somewhere, and at a certain time and date. When translated into relations and relationships, the data occupies roughly 24 data items in three tables.
WEATHER	Every incident has a weather report associated with it. Roughly 20 data items in a single table.
PERSON	Nearly every incident involves people, either as crewmembers of a boarded vessel, or aboard SAR case subjects, or both. Roughly 25 fields in two tables.
VESSEL	Nearly every incident also involves a boat. Roughly 34 data items in a single table.

SAR CASE — Information that is unique to SAR cases: unit case number, nature of distress, lives lost and saved. Roughly 10 data items in two tables.

BOARDING — Information that is unique to law enforcement boardings: boarding report number, name and rank of boarding officer, violation codes, and remarks. Roughly 19 data items in four tables.

The following pages are key excerpts from the design documents for this simple integrated system, describing the data objects, the relational diagram (Figure 22), and the data dictionary.

Requirements

I. Data Requirements

We defined six major objects in the environment of a Coast Guard field unit tracking operational data, which are:

- The VESSELs which are the subject of operations.
- The PERSONnel which are the subject of operations.
- The INCIDENTs which operations involve.
- The WEATHER at the time of an incident.
- The SAR CASEs which the unit conducts.
- The BOARDINGs which the unit conducts.

In defining the objects involved in this application, we began by considering, from our personal experience in the field, what general categories of information were involved in the SAR and LE missions. It was clear that both normally involve vessels, although some few missions do not; likewise, nearly all missions involve people. Also common to both mission areas are weather information and general descriptive data, such as position, date, and time. These four objects are part of nearly every mission; the mission-specific objects include details of the damage and nature of distress, for SAR cases, and of the boarding and any citations, for LE cases.

We validated these object definitions by examination of the paper forms presently in use: a SAR case folder, form CG-16130, and a Report of Boarding, form CG-4100. These forms are included as Appendix F.

Object Diagrams:

Incident Number
Latitude
Longitude
Distance
Date
Time
Time Zone
Depth of Water
Location Narrative
NavRules
Body of Water
County
Reporting Source$_{MV}$

VESSEL	MV
BOARDING	
SAR CASE	
PERSON	MV
WEATHER	

INCIDENT

Wind Direction
Wind Speed
Wave Direction
Wave Height
Swell Direction
Swell Height
Surf Height
Cloud Cover
Visibility
Fog
Precipitation
Barometer
Ceiling
Air Temperature
Sea Temperature
Local Sunrise/set time
Tide Height
Tidal Current Speed
Tidal Current Direction

INCIDENT

WEATHER

UCN
MUCN
Nature of Distress
Termination Status
Lives Saved
Lives Lost
Sub-units$_{MV}$

INCIDENT

SAR CASE

Boarding Report Number
Boarding Officer Name
Boarding Officer Rank
Owner-Operator Status
Viol Code$_{MV}$
Unsafe Condition Code$_{MV}$
Remarks$_{MV}$

INCIDENT

BOARDING

Driver's License number
Social Security number
First Name
Middle Initial
Last Name
Street Address
City
State
Zip
Phone
Birthdate
Sex
Height
Weight
Hair Color
Eye Color
Title
Personel Status
Courses
Missing after search?
Injuries Sustained$_{MV}$

INCIDENT MV

PERSON

Registration Number
Document Number
Name
Homeport
Nationality
Hull Ident Number
Sail Number
Radio Call Sign
RT License Number
Fish license Number
Make
Model
Model Year
Hull Material
Hull Color
Superstructure Color
Length
Draft
Net Tons
Propulsion
Horsepower
Use
Engine Compartment
Fuel Compartment
Construction
Type of Boat
Adult PFD's
Child PFD's
Equipment
POB
Missing after search?
Estimated $ Value
Damage $ in SAR

INCIDENT MV

VESSEL

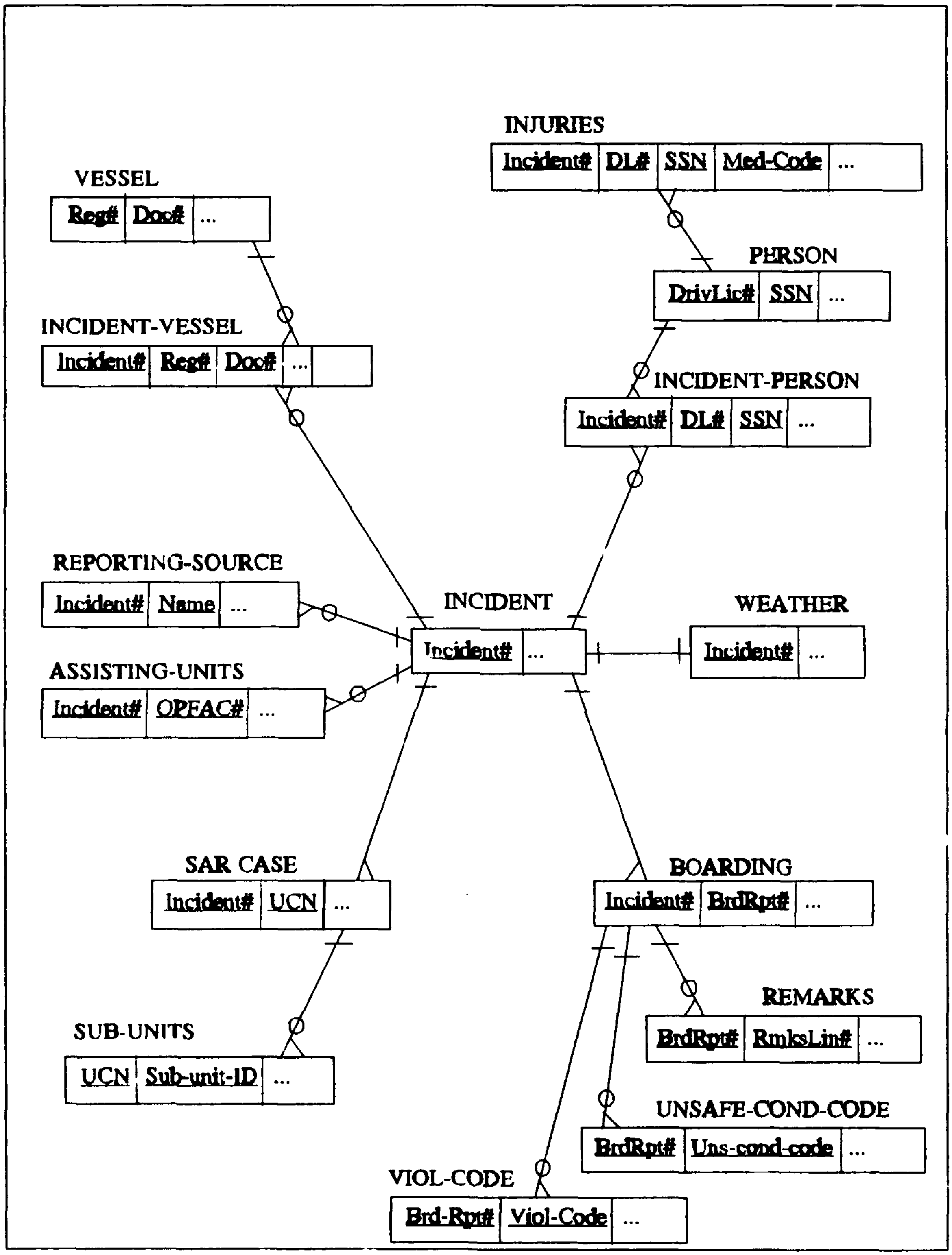

Figure 22: Relational Diagram.

Relation Definition:

Legend:

A## = alphanumeric, ## = field width
N = numeric
D = date
$ = dollar value
(underlined) = key
*** = foreign key*

INCIDENT

Incident#	A7
Latitude	A7
Longitude	A8
Distance	N
Date	D
Time	N
Time Zone	A1
Depth of Water	N
Location Narrative	A50
NavRules	A1
Body of Water	A40
County	A20

WEATHER

Incident#	A7
Wind Direction	N
Wind Speed	N
Wave Direction	N
Wave Height	N
Swell Direction	N
Swell Height	N
Surf Height	N
Cloud Cover	N
Visibility	N
Fog	A1
Precipitation	A4
Barometer	N
Ceiling	N
Air Temperature	N
Sea Temperature	N
Local Sunrise/set Time	N
Tide Height	N
Tidal Current Speed	N
Tidal Current Direction	N

SAR CASE

Incident#**	A7
Unit-case#	A7
Multi-unit-case#	A6
Nature-of-distress	A4
Termination-status	A1
Lives-saved	N
Lives-lost	N

BOARDING

Incident#**	A7
Boarding-report#	A7
Boarding-officer-name	A25
Boarding-officer-rank	A2
Own-op-status	A1

VESSEL		***PERSON***	
Registration#	A8	Driver's-License#	A15
Document#	A6	SSAN	N
Name	A30	First name	A20
Homeport	A30	Middle initial	A1
Nationality	A2	Last name	A25
Hull Ident Number	A17	Street Address	A45
Sail Number	A10	City	A2
Radio Call Sign	A8	State	N
RT License Number	A10	Zip	N
Fish license Number	A15	Phone	N
Make	A40	Birthdate	D
Model	A30	Height	N
Model year	N	Weight	N
Hull Material	A1	Hair Color	A3
Hull Color	A3	Eye Color	A3
Superstructure Color	A3	Title	A4
Length	N	Personnel Status	A1
Draft	N	Courses	A1
Net Tons	N	Missing after search?	A1
Propulsion	A1		
Horsepower	N		
Use	A1		
Engine Compartment	A1		
Fuel Compartment	A1		
Construction	A1		
Type of Boat	A1		
Adult PFD's	N		
Child PFD's	N		
Equipment	A12		
POB	N		
Missing after search?	A1		
Estimated $ value	$		
Damage $ in SAR	$		

REPORTING-SOURCE	
Incident#**	A7
Name	A40
Phone	N
Street Address	A45
City	A25
State	A2
Relationship	A50

ASSISTING UNITS	
Incident#**	A7
OPFAC#	N
Unit-name	A30
Their-Unit-case#	A7
Their-boarding-report#	A7

INCIDENT-PERSON	
Incident#**	A7
DL#**	A15
SSAN**	N
Crew-posit	A1

INCIDENT-VESSEL	
Incident#**	A7
Document#**	A6
Registration#**	A8

INJURIES	
Incident#**	A7
SSAN**	N
Driver's-license#**	A15
Medical-code#	A10
Remarks1	A60
Remarks2	A60

VIOL-CODE	
Incident#**	A7
Boarding-report#**	A7
Viol-code	A2
Remarks1	A60
Remarks2	A60

UNSAFE-COND-CODE	
Incident#**	A7
Boarding-report#**	A7
Unsafe-cond-code	A2
Remarks1	A6
Remarks2	A60

BOARDING REMARKS	
Incident#**	A7
Boarding-report#**	A60
Remarks-line#	A2
Remarks1	A60

SUB-UNITS	
Unit-case#	A7
Sub-unit-ID	A8
Sub-unit-type	A2

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